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Animal-Sediment Relationships
A Case Study of the Patapsco River

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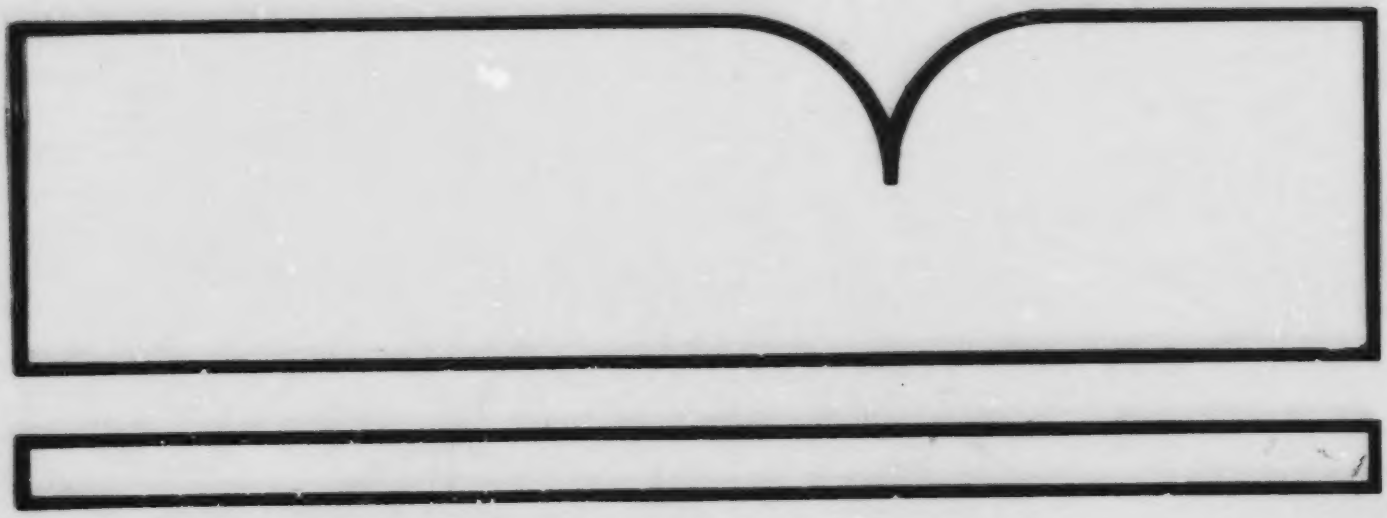

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ANIMAL-SEDIMENT RELATIONSHIPS:
A Case Study of the Patapsco River

by

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15. SUPPLEMENTARY NOTES

Extension of toxicant-related research from the main stem of Chesapeake Bay into the estuarine tributaries is important for two reasons: (1) many of the industrial sites and domestic activities are situated along the banks of these riverine systems, and (2) these subestuaries may function as closed basins in terms of sedimentation, trapping sediment-borne toxicants. The objectives of this study are as follows: (a) describe benthic community patterns in the Patapsco River compared to a reference area, the Rhode River, (b) characterize bioturbation levels and sedimentary structures in the two areas, (c) define sediment deposition rates (via ^{137}Cesium and pollen) along both subestuaries, and (d) define the histopathological condition of the bivalve, *Macoma balthica*, throughout the estuarine systems. Because of time constraints, sampling was limited to the mid-spring of 1981; a total of 18 sites was examined.

Based on benthic community patterns in this and other studies, the Patapsco River was divided into the following environmental regimes: polluted (head and peripheral branches), semi-polluted (central region), and semi-healthy (mouth). The Rhode River served as the reference environment. Diversity values increased toward the semi-healthy and reference areas. Generally, diversity was low compared to the main stem of the Chesapeake Bay. Most of the benthic community was concentrated in the top 10 cm of the sediment as in the main Bay. The deep-dwelling, equilibristic community became more significant in the gradient from polluted to semi-healthy and reference regimes. Polychaetous annelids proved to be the most successful of the deep-dwelling taxa.

Many of our samples manifested some evidence of bioturbation. Physically dominated areas and associated laminated sedimentary structures prevailed in the polluted regime. In contrast, bioturbation in the semi-healthy and reference environments had destroyed all evidence of physically-produced features. This increase in bioturbation from the head to the mouth of the Patapsco River mimics the trend in the main section of Chesapeake Bay.

Radionuclide (^{137}Cesium) and pollen dating reveal that direct physical mixing occurs at the sediment surface in the unstable, polluted region. This mixing may be the result of natural and/or anthropogenic events. Biogenic activities are principally responsible for the observed sediment resorting in the semi-healthy and reference areas.

The bibalve, *Macoma balthica*, was collected in all environmental regimes except the polluted area, where individuals were too small to be examined for significant pathological conditions. Only a few diseased clams were found. More diseased specimens are, however, likely to occur in late summer when stressed individuals are most susceptible to infection.

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ABSTRACT

Extension of toxics-related research from the main stem of the Chesapeake Bay into the estuarine tributaries is important for two reasons: (1) Many of the industrial sites and domestic activities are situated along the banks of these riverine systems, and (2) These subestuaries may function as closed basins in terms of sedimentation, trapping sediment-borne toxicants. The objectives of this study are as follows: (a) Describe benthic community patterns in the Patapsco River compared to a reference area, the Rhode River, (b) Characterize bioturbation levels and sedimentary structures in the two areas, (c) Define sediment deposition rates (via ^{137}Cesium and pollen) along both subestuaries, and (d) Define the histo-pathological condition of the bivalve, Macoma balthica, throughout the estuarine systems. Because of time constraints, sampling was limited to the mid-spring of 1981; with a total of 18 sites examined.

Based on benthic community patterns in this and other studies, the Patpasco River was divided into the following environmental regimes: polluted (head and peripheral branches), semi-polluted (central region), and semi-healthy (mouth). The Rhode River served as the reference environment. Diversity values increased towards the semi-healthy and reference areas. Generally, diversity was low compared to the main stem of the Chesapeake Bay. Most of the benthic community was concentrated in the top 10 cm. of the sediment as in the main Bay. The deep-dwelling, equilibristic community became more significant in the gradient from polluted to semi-healthy and reference regimes. Polychaetous annelids proved to be the most successful of the deep-dwelling taxa.

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Radionuclide (^{137}Cesium) and pollen dating reveal that direct physical mixing occurs at the sediment surface in the unstable, polluted region. This mixing may be the result of natural and/or anthropogenic events. Biogenic activities are principally responsible for the observed sediment resorting in the semi-healthy and reference areas.

The bivalve, Macoma balthica, was collected in all environmental regimes except for the polluted area, where individuals were too small to be examined for significant pathological conditions. Only a few diseased clams were found. More diseased specimens are, however, likely to occur in late summer when stressed individuals are most susceptible to infection.

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INTRODUCTION

The EPA-Chesapeake Bay Program was established to assess factors adversely affecting the Chesapeake Bay. Research efforts of the Toxic Substances Subprogram have focused on sediment properties and dynamics since most toxic materials tend to adhere to particulate material. These particulates eventually settle in bottom sediments where they are subjected to a host of biologically-mediated events.

Biological research in the main stem of the Chesapeake Bay has addressed the benthic effects on the potential fate of toxicants in bottom sediments (Nilsen, et al., 1980; Reinharz and O'Connell, 1981). These investigations have described the vertical distribution as well as the biogenic structures and processes of the macrofauna at locations where geochemical research was also conducted. The results of these studies indicate that most sediments in the estuary are highly bioturbated except in physically dominated areas (e.g. - upper reaches of the Bay) and areas characterized by fluid mud and periodic anoxia (e.g. - channel regime). Faunal concentrations and biological mixing of the sediment fabric are greatest in the top 10 cm. Biogenic reworking also occurs to 30 cm or more. The consequence of such extensive biotic disruptions along the Chesapeake Bay bottom is the remobilization and resuspension of toxic substances.

The Chesapeake Bay Program has expanded its efforts into the tributaries primarily because of the high concentration of industrial sites and domestic activities along these locations. Furthermore, these subestuaries may function as closed basins in terms of sedimentation, trapping sediment-borne toxicants. The accentuated conditions of heavily contaminated areas such as the Patapsco River necessitates the examination of the fate and effects of toxic substances within the sedimentary environment. It is our intention to augment our present base of knowledge of the state of these burdened tributaries as compared with that of the main Bay.

The objectives of this study are as follows: (a) Describe benthic community distribution patterns in the Patapsco River; (b) Characterize bioturbation levels and sedimentary structures along the Patapsco River bottom; (c) Define sediment deposition rates and mixing effects at certain areas throughout the tributary; namely through ^{137}Cesium and pollen analysis; and (d) Examine the histopathological condition of a selected bivalve, Macoma balthica, throughout the riverine systems. The Rhode River served as a reference for the Patapsco River. The Virginia Institute of Marine Science has conducted a comparable study of similar scope in the James, Elizabeth, and Ware Rivers. The long-term goal of these biological investigations is to synthesize the present data with information collated by other sedimentological and geochemical studies in order to provide a comprehensive picture of the Chesapeake Bay system.

METHODS

Sampling locations for the biological investigation were chosen to establish a fairly representative coverage of environmental regimes in the Patapsco and Rhode River systems. Eighteen sites were sampled during the mid-spring of 1981 (Figure 1) due to time constraints: 15 in the Patapsco River and 3 in the Rhode River. Latitude-longitude coordinates for each station are provided in Table 1. Most of the sample locations are in close proximity to those in previous studies (Johns Hopkins University, 1972; Pfitzenmeyer, 1975; U.S. Department of Transportation and Maryland Department of Transportation, 1979; Heck, Jr., 1980). Biological sampling was conducted in conjunction with the geochemical effort.

The United States Navy Electronics Laboratory (U.S. N.E.L.) spade box corer was utilized to extract a sediment surface of 0.063 m^2 with a maximum penetration of 60 cm. Two box cores were taken at each station; the first to sieve for benthic organisms, and the second for radiographic processing in addition to sediment, ^{137}Cesium, and pollen analysis. Much of the methodology employed in examining these samples are contained in the manuscript on the main Bay (Reinharz and O'Connell, 1981).

1. Physical Environment: Water Quality and Sediment Type

The water quality criteria considered in this study include bottom salinity and temperature. These parameters were measured with a Beckman Model RS-5 induction salinometer. Grain size analysis was also performed along the vertical axis of each core at the same increments discussed in section 2 below.

2. Benthic Distribution Patterns

The macrofaunal community was quantified by sieving the organisms through a 0.5 mm mesh screen at the following vertical intervals: 0-2 cm, 2-5 cm, and every 5 cm thereafter. All individuals were fixed, preserved, and stained for later identification to species level with the exception of the oligochaetes and insects. Oligochaete sp. is tentatively identified as Limnodrilus hoffmeisteri.

Species counts, the distribution of individuals and diversity indices were used to evaluate the condition of the benthic community. Specifically, Margalef's (1956) index of deversity (with some mathematical modifications) as well as redundancy values were applied to our data:

Diversity Index: $H' = -\Sigma(N_i/N)\log_2(N_i/N)$

$$H'MAX = (1/N)(\log_2 N! - S\log_2(N/S)!)$$

$$H'MIN = (1/N)(\log_2 N! - \log_2(N-S+1))$$

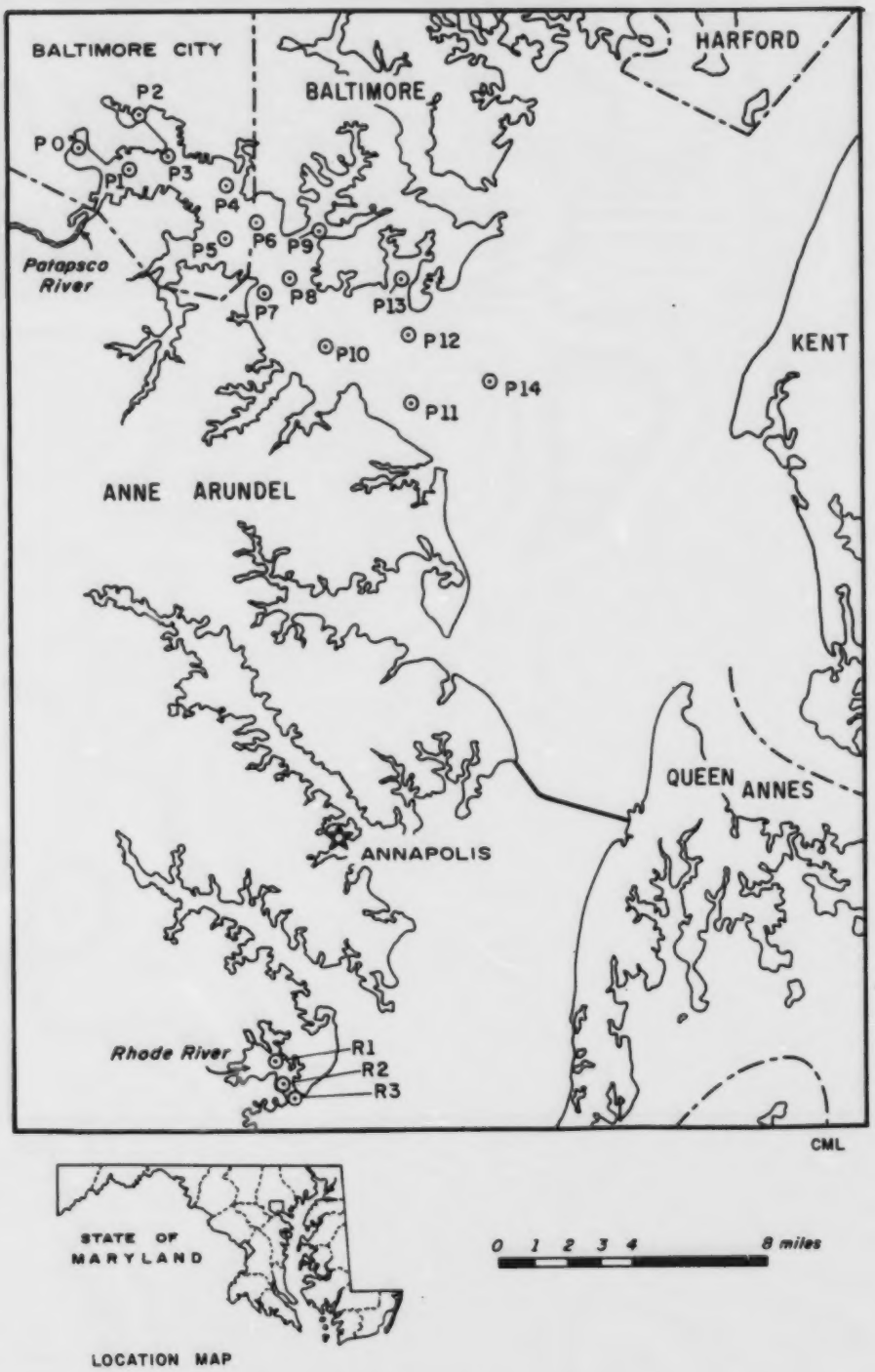

Figure 1: Sampling stations in the Patapsco and Rhode Rivers.

Table 1: Location, date, water depth, and bottom salinity and temperature for the Patapsco (P) and Rhode (R) River stations.

Sta. No.	Date	Latitude Longitude	Water Depth	Conductivity (mlmhos/cm)	Salinity (‰)	Temperature (°C)
P0	4/22/81	39°15'42" 76°37'37"	13'	14.10	10.70	12.30
P1	4/22/81	39°15'16" 76°36'02"	17'	14.61	11.37	12.63
P2	4/23/81	39°16'43" 76°35'32"	25'	15.14	11.52	12.78
P3	4/23/81	39°15'31" 76°34'28"	20'	14.80	11.50	12.70
P4	4/24/81	39°14'47" 76°33'03"	23'	13.58	9.86	14.32
P5	4/27/81	39°13'39" 76°33'00"	19'	15.16	11.74	12.68
P6	4/27/81	39°13'54" 76°31'32"	15'	14.58	11.14	13.12
P7	4/28/81	39°12'02" 76°31'11"	14'	14.00	10.69	13.34
P8	4/28/81	39°12'29" 76°30'32"	22'	14.24	10.04	17.30
P9	4/28/81	39°13'51" 76°29'54"	11'	13.97	10.42	13.98
P10	4/29/81	39°10'52" 76°29'38"	15'	14.98	11.27	13.82
P11	4/29/81	39°09'16" 76°27'00"	16'	12.57	9.10	15.38
P12	4/30/81	39°11'13" 76°27'07"	16'	12.50	8.76	16.28
P13	4/30/81	39°12'22" 76°27'10"	10'	12.89	9.34	14.70
P14	4/30/81	39°09'01" 76°23'25"	20'	14.42	10.92	13.04
R1	5/4/81	38°53'04" 76°31'20"	10'	17.80	12.31	20.28
R2	5/4/81	38°52'24" 76°31'05"	10'	17.51	12.45	17.27
R3	5/4/81	38°51'57" 76°30'48"	11'	17.80	12.90	15.73

Redundancy: $R = \frac{H'MAX - H'}{H'MAX - H'MIN}$

S = number of species

N = total number of specimens

N_i = number of specimens in the i^{th} taxon

We have observed that the diversity index (H') is usually greater than 3 in healthy regions, while it decreases to less than 1 in areas of heavy pollution. Redundancy (R), which represents the position of H' between theoretical maximum and minimum diversities, indicates the dominance of one or more species. Values for redundancy are largest for polluted areas.

Dominance of individual species was determined by McCloskey's Biological Index (1970) and compared with a numerical abundance ranking. The former index takes into account both species frequency and abundance.

3. Bioturbation and Sedimentary Structures

Techniques for radiographic processing are outlined in Howard and Frey (1975) and detailed in the main Bay report. As before, Kodak AA-5 Inudstrial X-ray film was used to produce the negatives.

4. Sediment Dating and Mixing: ^{137}Cesium and Pollen Analysis

Attempts were made to data 9 cores: 8 from the Patapsco River (Stations P0, P2, P3, P5, P7, P9, P10, and P14) and 1 from the Rhode River (Station R3). Each core measured ≈50 cm in length and was subsectioned into intervals similar to those mentioned in section 2. From each subsample, 1 ml of sediment was dried and treated with various acids for counts of ragweed and oak pollen. For ^{137}Cesium analysis, a portion of each subsample was oven dried at 105^{0}, weighed, and analyzed for ^{137}Cesium content on a Beckman gamma counter for 2000 seconds per sample. A New England Nuclear ^{137}Cesium standard and multiple background counts were used to quantify sample ^{137}Cesium levels. Procedures for this analysis followed methods described by Ritchie and McHenry (1973) and Ritchie, et al. (1973 and 1975).

5. Diagnosis of Parasitic and Pathogenic Conditions in the bivalve, *Macoma balthica*

The pathological condition of the bivalve, *Macoma balthica*, was examined because of its ubiquitous nature and bimodal feeding habit (surface deposit and occasional suspension feeder). A total of 593 clams were collected from 7 sites: 5 in the stressed environment of the Patapsco River (Stations P6, P8, P10, P12, and P14) and 2 in the reference environment of the Rhode River (Stations R1 and R3). Sample gathering was

accomplished with an oyster and anchor dredge with a 4 mm mesh net and a penetration greater than that of Macoma (>30 cm). Three size classes were examined (Small: <1 cm; Medium: 1-2 cm; Large: >2 cm). Clams at the head of the Patapsco River were generally smaller than the mesh size of the sampling net; therefore making it impossible to analyze these populations at any statistically significant level. A minimum of 50 individuals per station was required for analysis.

Shells of Macoma balthica were crushed and specimens placed in Davidson's fixitive (AFA-glycerine) for at least 24 hours. Fixitive was changed 2-3 times to decalcify the shells. Specimens were then placed in 95% ethanol for an hour, dehydrated, cleaned, and embedded in fresh paraffin. Specimens were sectioned at 7 microns and stained with Harris' hematoxylin and eosin.

RESULTS AND DISCUSSION

1. Physical Environment: Water Quality and Sediment Type

Water quality conditions of the Chesapeake Bay tributaries generally reflect trends in the main stem of the system. Less than a handful of studies have examined water criteria in the Patapsco River to any degree of thoroughness (Stroup, et al., 1961; Department of Water Resources, 1969; Pfitzenmeyer, 1975; U.S. Department of Transportation and Maryland Department of Transportation, 1979). Seasonal differences in bottom salinity were demonstrated to mimic the main Bay: lowest in spring and highest in fall. Highest bottom temperatures, typically occurring in the summer, were found to be inversely related to dissolved oxygen levels. Unlike the main Bay, these parameters as well as others (e.g. - pH) fluctuated only slightly between stations within the same season. The lack of a salinity gradient was considered to be the result of low fresh-water inflow at the Patapsco head. Salinity and temperature measurements during the time of this study also did not vary substantially throughout both tributaries; within 3‰ and $5^{o}C$ (Table 1). These values are comparable to those reported in previous research efforts.

Except for the head branches of the Patapsco River, sediment analysis also shows a spatial consistency; along the surface and at depth (Appendix I). Based on past and present studies, much of the tributary bottom falls in the silty-clay regime. Some sand margins are found at the south side of the river mouth. The sediments in our study are characteristically soft; generally having a water content of >50%. The high variability in sediment distribution at the Patapsco head is attributed to intense and continual dredging and spoil disposal operations, and shipping (e.g. - propeller wash) activities. The sediment trend in the Rhode River appears to be more typical of the main Bay; becoming coarser in its textural quality from the head to the mouth of the system.

2. Benthic Distribution Patterns

Faunal Composition

Habitat assessment of the macrofauna traditionally includes descriptions of species composition, the distribution of individuals and the diversity of the fauna. In order to evaluate our data for the purpose of historical perspecitve, the same biotic analyses were applied as those used by others (Pfitzenmeyer, 1975; U.S. Department of Transportation and Maryland Department of Transportation, 1979). The results of this one-season study are not conclusive enough to establish present trends.

Pfitzenmeyer (1975) divided the Patapsco River into gradients of health; comparing these regions to the reference area of the Chester River (Figure 2). Because of our limited data bank, a similar environmental regional breakdown was assigned to the Patapsco; with the Rhode River serving as the reference area. Species counts and diversity values (H') increased while redundancy (R), the degree of dominance, figures decreased towards the mouth of the Patapsco and away from its peripheral branches (Table 2).

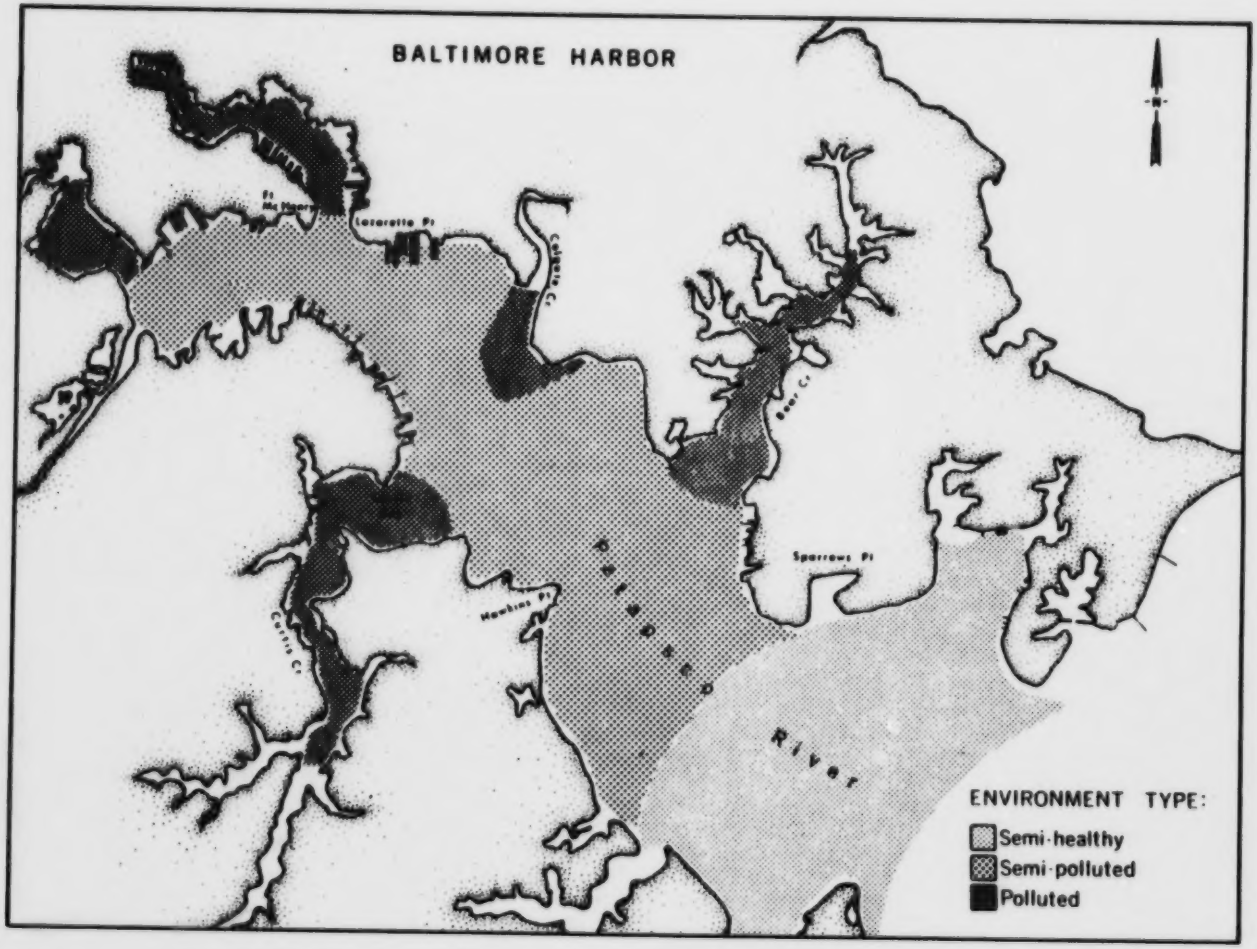

Figure 2: Environmental regimes in the Patapsco River (Pfitzenmeyer, 1975).

Table 2: Species counts and diversity indices for the Patapsco (P) and Rhode (R) River stations.

	Station No.	No. of Species	No. of Individuals	H'	H' Max	H' Min	R
Polluted	P0	5	2783	0.330	2.324	0.016	0.864
	P2	3	345	0.838	1.599	0.048	0.491
	P4	6	1443	0.590	2.595	0.036	0.783
	P5	4	814	0.246	2.001	0.035	0.893
	P9	5	389	0.678	2.279	0.088	0.731
Semi-Polluted	P1	8	1108	0.561	2.996	0.064	0.831
	P3	8	1036	0.343	2.996	0.068	0.906
	P6	9	319	1.615	3.158	0.208	0.523
	P7	10	538	1.416	3.340	0.152	0.603
	P8	8	540	1.173	2.969	0.116	0.630
Semi-Healthy	P10	10	603	1.296	3.300	0.138	0.634
	P11	11	737	1.192	3.411	0.129	0.676
	P12	16	429	2.879	4.019	0.305	0.307
	P13	8	505	1.400	2.956	0.123	0.549
	P14	14	516	2.715	3.843	0.226	0.312
Reference	R1	15	2277	2.286	3.893	0.068	0.420
	R2	13	1508	2.348	3.673	0.084	0.369
	R3	15	1633	2.501	3.893	0.091	0.366

The anomalous densities of individuals in the polluted and semi-polluted environments is due to the sporadic success of a few opportunistic species. Generally, benthic community diversity is comparable in range to previous investigations but is low relative to the main Bay.

For further comparative purposes, we divided the benthic community of the tributaries into the following taxonomic categories: annelids (polychaetes and oligochaetes), arthropods (crustaceans and insects), molluscs, and miscellaneous groups (namely nemerteans). A general listing of macrofaunal species is presented in Appendix II. All necessary compilations were made using the more detailed species and abundance data included in Appendix III.

A total of 12,105 individuals belonging to 18 species were found in the Patapsco River, while 5418 individuals belonging to 17 species were collected in the Rhode River. Annelids proved to be the dominant taxon in the Patapsco River; consisting of 7 species and comprising ≈90% of the population. This finding is consistent with other previous studies of this system (Johns Hopkins University, 1972; Pfitzenmeyer, 1975; Ecological Analysts, 1977; U.S. Department of Transportation and Maryland Department of Transportation, 1979; Heck, Jr., 1980). The remaining taxa were less well represented: arthropods (6 species, 2.3% of population), molluscs (4 species, 7.0% of population), and miscellaneous groups (1 species, 0.7% of population). In the Rhode River, both annelids (7 species, 39.2% of population) and arthropods (6 species 48.0% of population) are co-dominant taxa. Three species of molluscs comprised 12.6% of population and miscellaneous groups contained 1 species (0.2% of population). Fifteen out of 20 species were common to both tributaries.

All of the benthic species in this investigation were also found in past research efforts. Dominance was determined by using McCloskey's Biological Index (1970) and compared to a ranking based strictly on numerical abundance (Table 3). The list of dominants comprise ≈50% of all the species present in the specific environment. Both ranking methods show a striking similarity and compare favorably to earlier studies. Annelids are common in all environmental regimes, with Scolecolepides viridis representing the overwhelming dominant in the Patapsco River. High population densities of both Scolecolepides viridis and the mollusc, Macoma balthica, were found along the axis of this tributary. These densities are related to larval recruitment for both species; juveniles comprising ≥85% of the respective populations. The spawning season for Scolecolepides occurs in the spring (George, 1966) while that of Macoma is reported to occur during spring and fall (Gilbert, 1978). Arthropods and molluscs, other than Macoma balthica, become more significant towards the "healthier" environments.

Vertical Distribution of the Fauna

An examination of the vertical distribution of the macrofauna is important because of their role in the transport of nutrients and toxic substances; functioning as a link between the aerobic and anaerobic zones (Rhoads, 1974; Rhoads, et al., 1977). Such distribution patterns for the

Table 3: Dominant species based on McCloskey's Biological Index (1970) and numerical abundance, and maximum depth of penetration (cm).

Biological Index		Numerical Abundance	
Polluted			
1. *Scolecolepides viridis*	(20 cm)	1. *Scolecolepides viridis*	(20 cm)
2. *Macoma balthica*	(5 cm)	2. *Macoma balthica*	(5 cm)
3. Oligochaete sp.	(25 cm)	3. Oligochaete sp.	(25 cm)
4. *Eteone heteropoda*	(10 cm)	4. *Eteone heteropoda*	(10 cm)
5. *Nereis succinea*	(15 cm)	5. *Nereis succinea*	(15 cm)
Semi-Polluted			
1. *Scolecolepides viridis*	(20 cm)	1. *Scolecolepides viridis*	(20 cm)
2. *Macoma balthica*	(15 cm)	2. *Macoma balthica*	(15 cm)
3. *Eteone heteropoda*	(10 cm)	3. *Eteone heteropoda*	(10 cm)
4. *Streblospio benedicti*	(5 cm)	4. *Streblospio benedicti*	(5 cm)
5. Oligochaete sp.	(20 cm)	5. Oligochaete sp.	(20 cm)
Semi-Healthy			
1. *Scolecolepides viridis*	(20 cm)	1. *Scolecolepides viridis*	(20 cm)
2. Oligochaete sp.	(30 cm)	2. Oligochaete sp.	(30 cm)
3. *Heteromastus filiformis*	(40 cm)	3. *Leptocheirus plumulosus*	(10 cm)
4. *Streblospio benedicti*	(5 cm)	4. *Macoma balthica*	(25 cm)
5. *Macoma balthica*	(25 cm)	5. *Heteromastus filiformis*	(40 cm)
6. *Leptocheirus plumulosus*	(10 cm)	6. *Streblospio benedicti*	(5 cm)
7. *Eteone heteropoda*	(10 cm)	7. *Cyclaspis varians*	(2 cm)
8. *Corophium lacustre*	(2 cm)	8. *Eteone heteropoda*	(10 cm)
9. *Macoma mitchelli*	(15 cm)	9. *Macoma mitchelli*	(15 cm)
10. *Cyclaspis varians*	(2 cm)	10. *Nereis succinea*	(30 cm)
Reference			
1. *Leptocheirus plumulosus*	(10 cm)	1. *Leptocheirus plumulosus*	(10 cm)
2. Oligochaete sp.	(20 cm)	2. Oligochaete sp.	(20 cm)
3. *Streblospio benedicti*	(5 cm)	3. *Streblospio benedicti*	(5 cm)
4. *Macoma balthica*	(30 cm)	4. *Macoma balthica*	(30 cm)
5. *Cyclaspis varians*	(2 cm)	5. *Cyclaspis varians*	(2 cm)
6. *Heteromastus filiformis*	(40 cm)	6. *Heteromastus filiformis*	(40 cm)
7. *Scolecolepides viridis*	(20 cm)	7. *Scolecolepides viridis*	(20 cm)
8. *Macoma mitchelli*	(15 cm)	8. *Macoma mitchelli*	(15 cm)
9. *Corophium lacustre*	(5 cm)	9. *Corophium lacustre*	(5 cm)
10. *Nereis succinea*	(40 cm)	10. *Eteone heteropoda*	(2 cm)

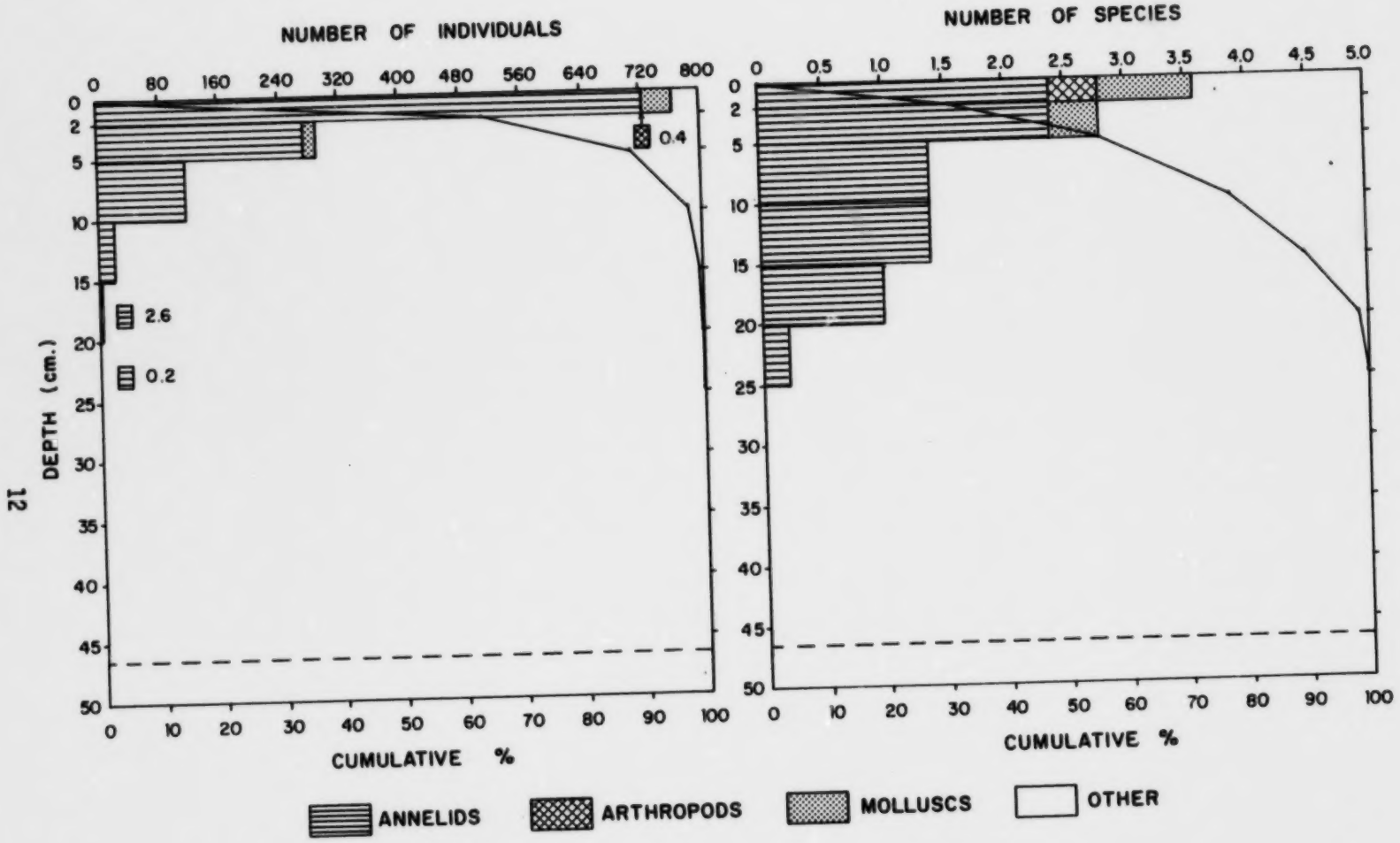

Figure 3: Vertical distribution of the macrobenthos in the polluted environment (Patapsco River).

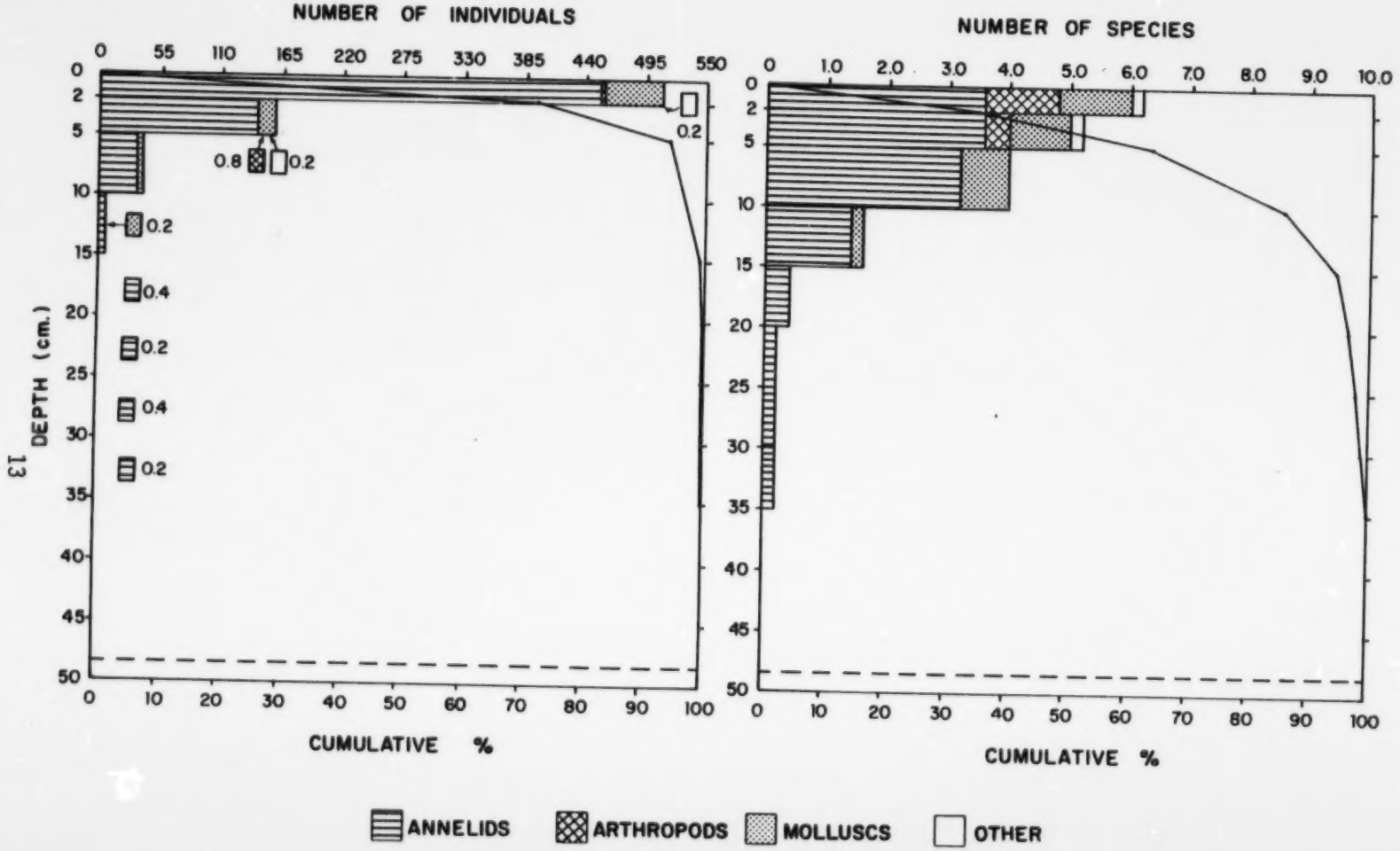

Figure 4: Vertical distribution of the macrobenthos in the semi-polluted environment (Patapsco River).

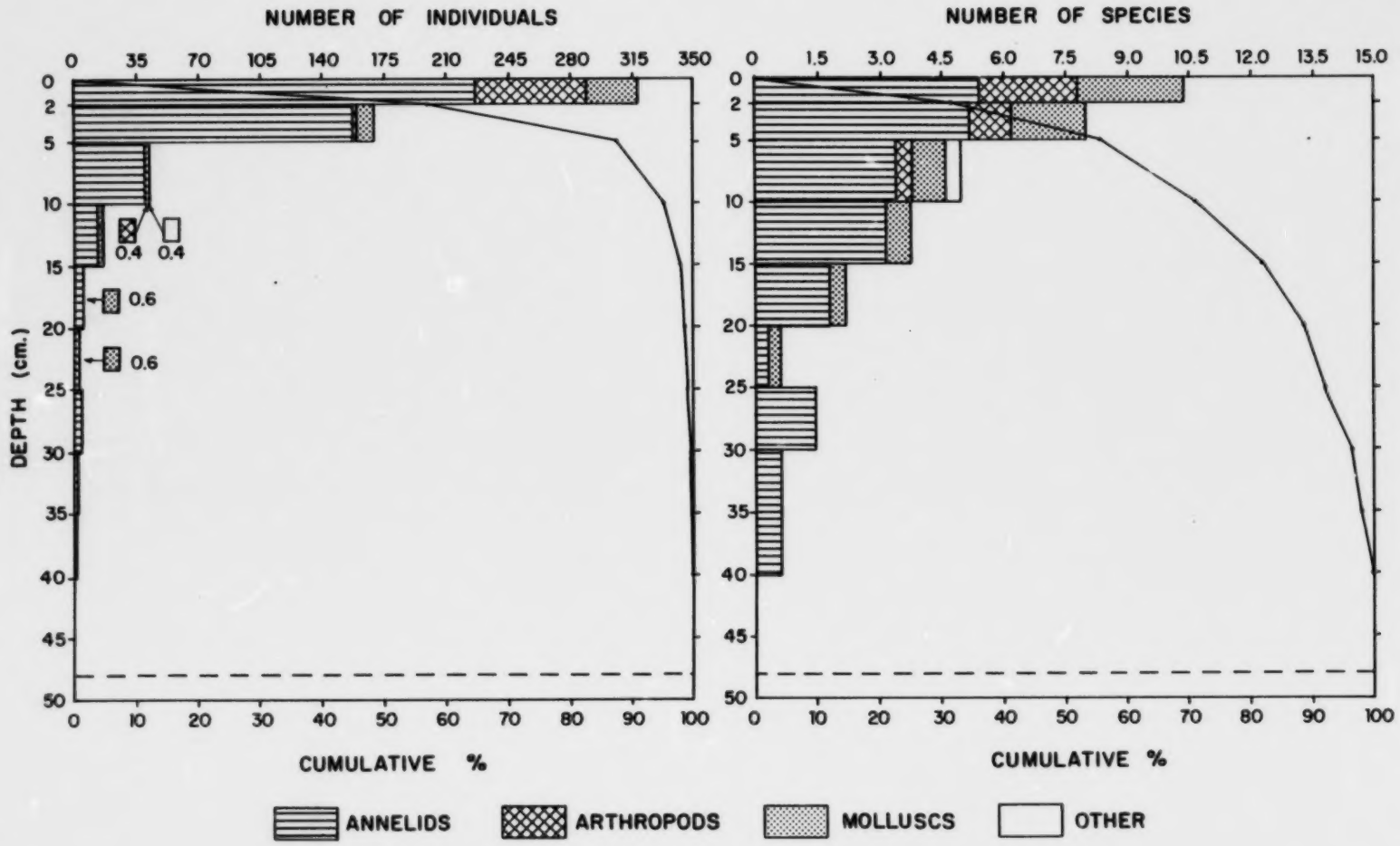

Figure 5: Vertical distribution of the macrobenthos in the semi-healthy environment (Patapsco River).

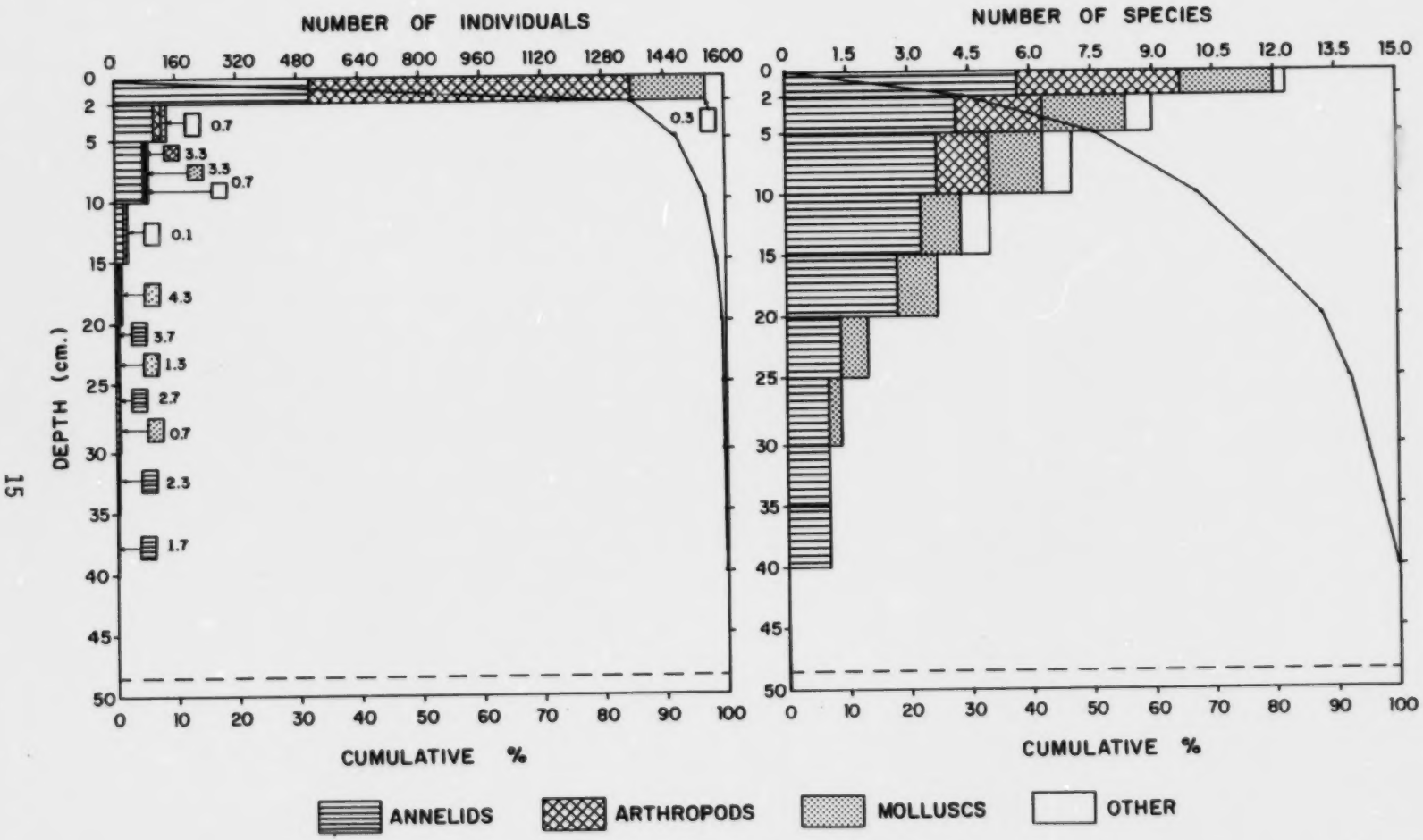

Figure 6: Vertical distribution of the macrobenthos in the reference environment (Rhode River).

Patapsco and Rhode (reference) River environments are presented in Figures 3-6. The solid line represents the cumulative percent of the number of individuals or species with depth. The dashed line represents the average depth of penetration for these areas. The average penetration for all stations was 48 cm.

As in the main Bay (Reinharz and O'Connell, 1981), most of the benthic community is concentrated in the top 10 cm. Greater than 85% of all individuals occupy the upper 5 cm of the sediment strata and ≥95% of population are found in the top 10 cm. All of the species collected were also found in the top 5 cm of the sediment. Although the percent distribution of individuals in the upper sediment strata of the Patapsco is higher than the cumulative figures presented in the main Bay text, these areas exhibit comparable distribution percentages during the same season.

Despite the predominance of surface-dwellers in the tributaries, a prominent deep-dwelling fauna (defined as organisms living below 10 cm) does flourish. There is a general increase in the number of deep-dwelling individuals and species in the gradient from polluted to reference environments. Annelids proved to be the most successful deep-dwelling group (also refer to Table 3).

In none of the stations did any species living below 10 cm exceed 10% of the total population. However, a number of organisms do exceed 10% or more of their own species populations below this zone: Oligochaete sp., Heteromastus filiformis, Macoma balthica, and Nereis succinea. As in the main Bay, these are the same species that are likely to be undersampled in studies that examine only the upper 10 cm of the sediment.

Many of the surface-dwelling dominants (e.g. - Scolecolepides viridis, Streblospio benedicti, Leptocheirus plumulosus) have an opportunistic or fugitive life style. These species are characterized by their rapid population increases, effective dispersal mechanism and high mortality (Grassle and Grassle, 1974). Other common deep-dwelling organisms (e.g. adult Macoma balthica, Heteromastus filiformis, Nereis succinea, Oligochaete sp.) show some tolerance to anoxic conditions (Odhner, 1978). Most of these species have the capacity to recover from periodic stresses.

3. Bioturbation and Sedimentary Structures

X-radiography is used in this study since it depicts detailed structures of the sedimentary environment. Physical and/or biogenic features are indicative of various environmental conditions. The percentage of physical disruption created by the fauna is defined by the degree of bioturbation and follows the scheme of Howard and Frey, 1972; 0%, trace, <30%, 30-60%, 60-90%, 90-99%, 100%. Like most areas of the Chesapeake Bay, nearly all the samples in the Patapsco and Rhode Rivers manifest some evidence of bioturbation (Table 4). Representative radiographs of various environmental regimes are shown in Appendix IV.

The intense dynamics of the physical regime in the polluted environment and the small size and transitory nature of the fauna in these areas are

Table 4: Bioturbation levels for sampling stations in the Patapsco (P) and Rhode (R) Rivers based on a modified classification scheme of Howard and Frey, 1972.

Degree of Bioturbation (%)	Stations
0	P0, P2
trace	P4
<30	P1, P5, P9
30-60	P3, P7, P8
60-90	P6, P10, P12, P13
90-99	P11, P14, R1, R2, R3
100	none

demonstrated by the preservation of laminar structures (Plates 1 and 2). The sediments in the tributary branches are characterized by fluid mud laminae, with thin interlayered sand laminae observed at the head of the system. Occasionally, shell lag deposits are also evidenced. Anthropogenic inputs, such as slag, as well as other debris (e.g. - sticks, leaf matter) are commonplace. Many of the species in this region are surface tube-dwellers or juvenile burrow-builders. These faunal components do not naturally destroy physical structures to any significant extent because of their sedentary life-habit, early life-cycle stage, or low density. However, laminar disruption is apparent in some cores (e.g. - Station P2). Such turbation is thought to be the result of the upward migration of methane gas (Martin and val Klump, 1980). No remnant shell concentrations were found despite high densities of the juvenile bivalve, Macoma balthica, at a few stations at the Patapsco head branches, suggesting strong washout by flushing actions in this area.

The semi-polluted environment represents a dynamically intermediate zone (Plates 3 and 4). Phases of biological and physical activity often occur in these sediments. Moderately disrupted mud and/or interbedded sand layers are typically found in this regime. Shells and shell fragments, pebbles and coarse sand particles, and slag are scattered throughout many of the stations. At some locations, (e.g. - Station P0), physical features can be attributed to the anthropogenic effects of dredging and spoil disposal. A more diverse faunal pattern allows for some disruption of physically-produced sedimentary structures.

In the semi-healthy and reference environments, very few if any physical sedimentary features are evident (Plates 5, 6 and 7). Laminated structures that do form are presumably destroyed by biogenic reworking. These environments are represented by a greater diversity of deep-dwelling permanent as well as temporary burrowers and tube builders. In some cases, a complex geometry of biogenic structures is present along the length of the cores. In other cases, nearly complete homogenization is seen; only large biogenic structures are identifiable. Shell layers of the bivalve, Rangia cuneata, which represents a death assemblage, commonly occur in the semi-healthy region of the Patapsco River.

The majority of biogenic structures are produced by polychaetous annelids. The most prominent features are those of Scoleolepides viridis (polluted to semi-healthy environments), Macoma balthica (semi-polluted, semi-healthy and reference environments) and Nereis succinea (semi-healthy and reference environments). Biodepositional features were uncommon.

4. Sediment Dating and Mixing: ^{137}Cesium and Pollen Analysis

The assignment of dates to sediment layers provides researchers with a chronology for the examination of pollution in the system in question. This study has employed both traditional (pollen) and non-traditional (radionuclides, specifically ^{137}Cesium) methods to ascertain sedimentation rates for a number of stations in the Patapsco and Rhode Rivers. ^{137}Cesium deposits are widespread in the enivornment as a result of nuclear weapons testing ≈29 years ago; its horizon is identified between 1962 and 1963.

Pollen profiles are identified with maximum watershed clearance for agriculture; its horizon is marked in the sediments by a large increase in ragweed pollen and a marked change in the ratio of oak to ragweed. The date for the pollen horizon is 1890 for the Patapsco River and 1840 for the Rhode River.

Graphs are included to show ^{137}Cesium levels versus sediment depth for each station (Figure 7). A tabulation of actual data values is furnished in Appendix V. The results obtained varied widely between stations; therefore, the results from each station will be discussed separately.

Station P14 and R3 (bioturbation level at 90-99%) show definite ^{137}Cesium peaks. Both stations have peaks at the 10-15 cm stratum, giving these sites an estimated deposition rate between 0.56 and 0.83 cm/yr. This deposition rate for Station P14 is consistent with ^{210}Pb data at the same location (0.88 cm/yr). The magnitude of the peaks is comparable with levels found in the literature, but is somewhat lower than those found in studies of Maryland aquatic systems. The fact that sediment deposited after the ^{137}Cesium peak did not have values equal to background levels (sediment depth 20-50 cm) indicates that there was some resuspension or vertical mixing, predominantly through biogenic reworking of sediments after 1963.

Pollen analysis at Stations P14 and R3 did not yield an agricultural horizon. This is probably because the cores were too short and the sedimentation rate too high to include sediments deposited in 1890 and 1840. A great deal of variation existed in the oak-ragweed ratio in P14, suggesting that there was considerable sorting of pollen and sediments due to biotic activity.

The ^{137}Cesium profiles at Stations P9 and P3 (bioturbation level at <30 for P9, 30-60% for P3) are more difficult to interpret. Both show ^{137}Cesium levels at lower levels (35-40 cm for P9; 30-35 cm for P3). Assuming deposition of this sediment during 1963, a sedimentation rate of approximately 1.94 to 2.22 cm/yr and 1.67 to 1.94 cm/yr is projected for Stations P9 and P3 respectively. Both stations also show ^{137}Cesium peaks of greater magnitude between 10-15 cm (p9) and 15-20 cm (P3) than at the base peaks. These upper strata peaks correspond to deposition of ^{137}Cesium-laden sediments between 1973 and 1976. No sources of atmospheric ^{137}Cesium have been reported for this period. Therefore, we must assume that either sediments enriched with ^{137}Cesium were deposited during this period, or that there was continuous physical resuspension between 1963 and 1973, with a period of diminished resuspension between 1973 and 1976.

There is no agricultural horizon in the P9 pollen profile, probably because of a high rate of sediment deposition. The horizon does appear to be present at Station P3 at 35-40 cm, yielding an average sedimentation rate between 0.38 and 0.44 cm/yr since 1890. There is considerable discrepancy between the ^{137}Cesium and pollen data at this station.

The ^{137}Cesium profile from Station P10 (bioturbation level at 60-90%) shows a definite peak between 40 and 50 cm; indicating a sedimentation rate

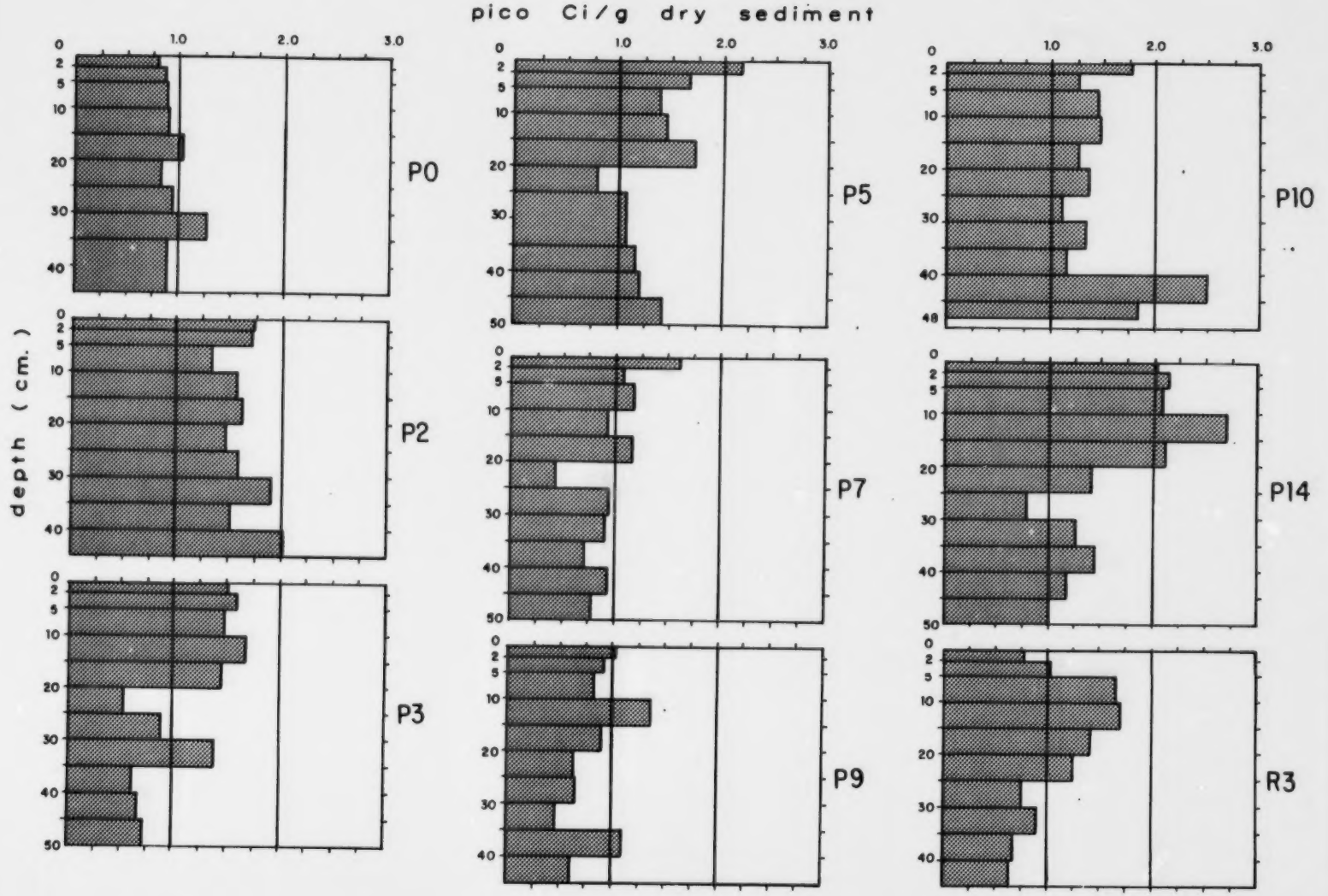

Figure 7: ^{137}Cesium profiles for selected stations in the Patapsco (P) and Rhode (R) Rivers.

of 2.20 to 2.50 cm/yr. However, two points of interest should be mentioned. First, the depth of the core taken did not allow the profile to return to a pre-deposition background level. Therefore, we cannot conclude that a higher peak did not occur at a deeper depth and that a higher sedimentation rate existed. Secondly, there is a smaller peak at the sediment surface. ^{137}Cesium has been shown to selectively bind to fine-grained particles (Davis, 1963). If resuspension or mixing (biogenic as in Station P10, or physical as in Station P5 below) is continuous, and such resorting is greater than the sediment rate of ^{137}Cesium-laden particles, then a surface peak should persist over time. This peak would exhibit a lower radioactive level due to continuous input and dilution by sediment not enriched with ^{137}Cesium. The pollen profile for Station P10 does not contain any agricultural horizon.

Station P5 (bioturbation level at <30%) shows a ^{137}Cesium profile somewhat similar to Station P10. Peaks of varying magnitude exist at the surface, at 15 to 20 cm, and at 45 to 50 cm depths. The same explanation can be offered for the surface peak in this core as for that of P10. The 15 to 20 cm can be explained as a result of deposition. Finally, the depth of the core did not allow a return to pre-deposition background levels, and therefore no 1963 peak deposition may be conclusively defined. The pollen profile indicates that the 1890 horizon may be present between 45 and 50 cm. This would yield a sedimentation rate between 0.50 and 0.55 cm/yr since 1890.

Stations P7, P2 and P1 (bioturbation level at 30-60% for P7; <30% for P1; 0% for P2) do not show definite ^{137}Cesium peaks. Several explanations are possible. The cores may not have been taken to the proper depth (e.g. - sedimentation rate since 1963 is greater than the depth of the core taken). Laboratory procedures might have caused the peak to be missed. A 5 cm section of core might be so long that during subsampling, the portion of the 5 cm section containing the ^{137}Cesium fraction was physically missed. Another factor might be that during the early 1960's the sedimentation rate might have been low; and by equally subsampling a 5 cm section, the small ^{137}Cesium fraction was diluted by surrounding sediments not laden with ^{137}Cesium. Physically-produced resuspension and mixing activities could also account for a lack of a peak center, especially at Stations P1 and P2. Studies have shown that there is minimal vertical migration of ^{137}Cesium through undisturbed sediments (Robbins and Edginton, 1975). Therefore, if a relatively uniform profile is found, such resuspension and mixing are probable factors.

Pollen profiles at Stations P1 and P2 do not contain an agricultural horizon. However, the variable oak-ragweed ratios at Station P7 suggest that there may have been resorting of pollen and sediment, possibly the result of biogenic reworking.

5. Diagnosis of Parasites and Pathogenic Conditions in Macoma balthica

Histopathological studies were conducted on bivalve populations of Macoma balthica to determine potential adverse effects in the Patapsco River. Macoma balthica is an infaunal species that burrows up to 30 cm

deep in soft-mud bottoms. The depth to which this species burrows allows it to escape certain physio-chemical stresses (e.g. - warm temperatures). The ubiquity and varied feeding habits (surface deposit and suspension feeder) of this clam render it a desirable candidate for pathogenic investigations.

A tabulation of Macoma balthica collections is included in Table 5. Several size classes were analyzed. The smallest (<1 cm) individuals were probably fall 1980 spatfalls. The medium clams (1-2 cm) are most likely one year old and possibly older. The large clams (>2 cm) may have been 2 or more years old. A summary of pathogenic conditions found in Macoma balthica is given in Table 6. These conditions are discussed in the following sections.

Perkinsus marinus in Macoma balthica

The disease of bivalves caused by the apicomplexan Perkinsus marinus, previously called Dermocystidium marinus, (Mackin, et al., 1950) requires a long warm season to cause significant mortalities. In the 1950's, it caused up to 90% of oyster deaths in lower Chesapeake Bay (Andrews, 1979). The disease has been diagnosed by thioglycollate tests since 1950 (Ray, 1952). While studying oyster mortalities in Virginia, it was discovered that P. marinus, or other related species, were present in 16 other species of bivalves (Andrews, 1954). Pathogenicity appeared to be low because only light infections were found in bivalves other than oysters. Infections in some species tended to persist throughout the year, whereas oysters recover from most infections rapidly in late fall when temperatures drop below 20°C (Andrews, 1967). However, latent infections persist in a few oysters throughout the winter and spring. These spring and winter infections become the sources for earlier infection and heavier mortalities during the second year of P. marinus activity.

In the early 1950's, Perkinsus species in Macoma balthica was one of the most pathogenic of the parasites found in bivalves (Andrews, 1954; Valiulis and Mackin, 1969). This pathogen seemed to flourish throughout the year, and it was found in all the clams tested. The distribution of this Macoma parasite in Chesapeake Bay was never determined. Perkinsus was scarce in the collections of Macoma from the Patapsco and Rhode Rivers. If the M. balthica apicomplexan parasite is a warm season pathogen, the collections during mid-spring are not truly representative of its importance. Furthermore, a large portion of the clams collected were juveniles, and possibly had not yet been exposed to this parasite. Small oysters exhibit considerably more resistance to apicomplexan infections than older, larger oysters. This tendency is also applicable to Macoma. Perkinsus was occasionally found in adult clams at Station P6 of the semi-polluted environment. A far more reliable evaluation of the role of Perkinsus in the Patapsco River would be to perform thioglycollate tests in late summer. These tests are far more sensitive as a diagnostic technique than stained slides of other bivalve pathogens.

A number of clams exhibited other conditions that could not be diagnosed as to their pathogenic origins. Plasmodia appeared in several

Table 5: Summary of Macoma balthica collections in the Patapsco (P) and Rhode (R) Rivers.

Station	Slide Identification No.	No. of Individuals Examined
P6	9455-9477; 9703-9706 (34 slides)	78 small, 15 large
P8	9478-9495; 9707-9716 (52 slides)	34 small, 19 large
P10	9496-9519 (30 slides)	70 small, 16 large
P12	9520-9544; 9717-9719 (37 slides)	71 small, 20 large
P14	9545-9571 (32 slides)	61 small, 20 large
R1	9572-9607 (40 slides)	57 small, 30 large
R3	9608-9649 (48 slides)	67 small, 35 large

Table 6: Summary of parasitic and pathogenic conditions found in *Macoma balthica* in the Patapsco and Rhode Rivers.

	No. of Cases					
Stations	Perkinsus	Bacteria	Glandular Cysts	Pink Plasmodia	L. dark cells	Neoplasm
P6	2	1	1	2(?)	1	-
P8	1	-	-	-	1	-
P10	-	-	-	-	-	-
P12	2	-	-	-	-	-
P14	2	-	-	-	-	-
R1	-	1	1	-	-	-
R3	2	-	4	-	-	1

specimens. However, diagnosis is difficult when hemocytes are very abundant or become enlarged. Only one clam had an abundance of hemocytes that suggested a neoplasm.

Bacteria

Bacteria were rarely seen in Macoma; bacteria typically occurring only as a localized phenomenon. Such localized very fine stippling may also have been an artifact of tissue processing. Nevertheless, bacteria were found to be of negligible significance in this study.

Reproductive Organs

The storage cells become the sites of gonad development in Macoma. These tissues are compartmentilized by thin membranes where oogania and sperm develop. Sexual products were rare in the spring collections.

Reproductive potential was determined by examining parenchyma tissue. This tissue was abundant in the large clams (>2 cm) but very scarce in smaller individuals. Special attention was given to these inactive storage tissues in the search for systemic diseases such as Perkinsus. It was here that clams were rated for normal tissues versus reactions indicated by hemocytic abundances. Gill tissues were always "busy" with an abundance of nuclei. Patches of nuclei were often seen in parenchyma at the base of gills. Small clams always had "busy" tissues compared to larger ones. This activity in the smaller clams can be attributed to their rapid growth rate.

Waste Cells ("Gland" Tissue)

Irregular tissue patches were examined which showed strong hemocytosis; the first symptom of pathogenic conditions. Such patches contained large clear or pink-spotted cells that appear to be phagocytized. These cells are always packed close together, vary widely in size, and are considered to be "waste" cells. They are commonly found between the tubules of the digestive gland and were thought to be glands of some sort. Later they were cited in isolated parenchymal tissue associated with heavy nucleation of hemocytes; however, these cells were still packed closely together in irregular patches. These patches suggest a pathogenic situation because they occur in only a few oysters and less than a dozen clams.

Foot

No signs of pathogenic conditions were found in the foot. A series of heavily nucleated cells, resulting from rapid division, follows the outer contour of the foot. These usually stain as large dark purple blotches, due to deterioration that permitted nuclear materials to fill the cells. These actively dividing cells were rarely seen in better detail as closely clustered groups of three or four cells with small nuclei.

Hemocytic Reaction

Systemic hemocytosis is best observed in parenchymal tissue. Clams in the Patapsco and Rhode Rivers were usually free of serious hemocytosis. Only a few clams had general reactions that indicate severe infections. Much more common were patchy reactions of very localized tissues. Signs of hemocytic reaction were most often seen in the digestive gland or tubules.

No definite parasitic condition could be linked with hemocytic reaction except for the "waste cell" patches. There was often a scattering of early oocytes along the dividing membrane of the storage or gonad tissue.

SUMMARY

A comprehensive examination of the Patapsco River was undertaken in order to ascertain cause-effect relationships between the benthic community and the sedimentary environment. A number of disciplines were examined: biological (faunal composition and vertical distribution patterns), sedimentological (water quality criteria such as salinity and temperature, sediment distribution and radiographic observations), radiochemical (^{137}Cesium as well as pollen sediment dating and mixing), and histopathological (parasitic and pathogenic condition of the bivalve, Macoma balthica). This investigation was carried out in the mid-spring of 1981 in conjunction with the geochemical effort.

Comparison of prior investigations reveals shifts in the benthic community structure along the axis of the Patapsco River (Johns Hopkins University, 1972; Pfitzenmeyer, 1975; Ecological Analysts, 1977; U.S. Department of Transportation and Maryland Department of Transportation, 1979; Heck, Jr., 1980). The lack of discernible trends in the physical environment of this system, especially in salinity, sediment type and sedimentation rate, suggests that other factors are important in controlling the macrofauna. The depressed pH levels in some of the tributary branches (reported to average between 5.2 and 6.4 in Bear and Curtis Creeks) may be partly responsible for the reduced populations found in these areas (Stroup, et al., 1961; Department of Water Resources, 1969).

Based on various biotic indices in this and previous studies (Pfitzenmeyer, 1975, U.S. Department of Transportation and Maryland Department of Transportation, 1979) the Patapsco River was divided into the following environmental regimes: polluted, semi-polluted and semi-healthy. The Rhode River served as the reference environment. In the semi-healthy and reference areas. species counts and the diversity index increased while redundancy values decreased. Annelids emerged as the major taxonomic group. The polychaete, Scolecolepides viridis, was the overwhelming dominant species. High densities of both Scolecolepides and the bivalve, Macoma balthica, were found throughout the length of the tributary. Arthropods and molluscs, other than Macoma, became more significant in the healthier region of the Patapsco River.

The benthic community is concentrated in the top 10 cm of the sediment column as in the main stem of the Chesapeake Bay (Nilsen, et al., 1980; Reinharz and O'Connell, 1981). There was an increase in the deep-dwelling community in the gradient from polluted to reference areas. Again, annelids proved to be the most successful deep-dwelling group. Many of the species identified are highly resistant or resilient to periodic enviornmental disturbances.

The evidence in this report, especially that of radiographic prints, demonstrates the degree to which the intensity and frequency of physical disturbance regulate benthic population patterns. There was a prevalence of physical sedimentary structures at the peripheral branches and head of the Patapsco River. Stratigraphic preservation occurs only in the highly disturbed areas where species cannot establish themselves long enough

to rework the sediment. A constant state of opportunism exists in the polluted environment of the tributary. Populations are comprised mainly of surface-dwellers with short residence spans. In the semi-healthy and reference environments, bioturbation levels are high due to a more permanent and equilibristic, deep-dwelling population. Here, physical features are rarely, if ever, preserved; the sediments appear fairly homogenous. This finding indicates conditions similar to those of the main Bay and other regions of the United States (McCall, 1977; Rhoads, et al., 1978).

The degree to which sediment mixing occurs as manifested in ^{137}Cesium and pollen resorting is reflective of the environmental milieu. In unstable areas, such as the branches and head of the Patapsco, direct physical mixing typically occurs in the top 5 cm. Continuous resuspension and redeposition of ^{137}Cesium-enriched sediments appear to have contributed to the uniform ^{137}Cesium profiles observed there. This type of mixing may be caused by a number of events: natural forces - storms, or continuous occurrences such as waves, tides and currents; anthropogenic events - dredging and spoil disposal operations, or shipping traffic. Biogenic reworking is primarily responsible for the dispersal of ^{137}Cesium-laden sediment in the top 10-15 cm in the semi-healthy and reference regions. This finding is consistent with the vertical distribution profiles of the benthic community. Core penetration was apparently too shallow to extract pollen horizons or trends. Mixing depths as determined by ^{137}Cesium in the Patapsco-Rhode River systems are also comparable to the ^{210}Pb values in the main Bay (Goldhaber, et al., 1978). Goldhaber and others noted that mixing extends from 5 cm in the upper Bay to 20 cm in the central Bay regions.

The bivalve, Macoma balthica, in the semi-polluted and semi-healthy areas of the Patapsco River and the reference region of the Rhode River were examined for significant pathological conditions. Because of the small size of Macoma in the polluted regimes, no individuals were collected. Out of all the clams analyzed, only a few were found diseased. This finding is based on the low level of hemocytic reaction in the storage tissues. Infections of Macoma by the parasite, Perkinsus marinus, were rare; possibly because of the affinity of Perkinsus for warm temperatures and the clam for cold temperatures. Bacterial anomalies did not occur. No diseases were observed in other tissue systems such as the mantle, gills, siphons, digestive system or foot. No spawning had yet occurred in the spring, and only very early stages of gametogenisis had taken place. Comparative analysis with Macoma balthica populations elsewhere in the Chesapeake Bay indicates no apparent adverse effects on the same molluscan species (Farley, 1976; Farley, 1977). The greatest pathogenic effects are expected to occur in late summer when stressed clams are most susceptible to infection. Such follow-up sampling is highly recommended.

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Appendix I: Grain size distribution taken at vertical increments along box cores.

Tributary	Station No. (Collection Date)	Depth Interval (cm)	%H_2O	%Sand	%Silt	%Clay
Patapsco River	P0 (4/22/81)	0-2	66.25	35.34	36.51	28.14
		2-5	61.98	31.89	38.53	29.58
		5-10	57.05	31.35	44.80	23.85
		10-15	61.27	29.82	44.39	25.80
		15-20	57.13	24.85	47.94	27.21
		20-25	62.15	21.48	51.91	26.61
		25-30	61.23	22.02	49.48	28.50
		30-35	40.17	53.50	39.81	14.69
	P1 (4/22/81)	0-2	70.10	15.05	39.51	45.44
		2-5	67.35	15.39	41.04	43.62
		5-10	64.17	16.34	42.88	40.78
		10-15	52.03	46.71	28.59	24.70
		15-20	41.96	87.18	5.63	7.19
		20-25	57.66	21.09	37.37	41.55
		25-30	61.98	10.48	54.92	34.59
		30-35	59.62	12.13	56.27	31.60
		35-40	54.74	11.42	60.30	28.28
	P2 (4/23/81)	0-2	86.86	15.31	37.23	47.46
		2-5	72.72	21.35	36.84	41.81
		5-10	78.62	17.96	35.14	46.90
		10-15	75.30	20.48	29.56	49.96
		15-20	75.57	7.73	34.20	58.07
		20-25	75.18	14.24	31.98	53.78
		25-30	71.15	14.21	33.32	52.47
		30-35	72.87	11.87	32.13	56.00
		35-40	69.60	15.95	31.77	52.88
		40-45	69.93	11.21	33.68	55.11
		45-50	71.79	10.88	33.86	55.26
	P3 (4/23/81)	0-2	86.46	3.32	30.27	66.41
		2-5	76.06	2.66	27.96	69.38
		5-10	74.17	0.68	32.48	66.84
		10-15	68.07	0.55	39.34	60.11
		15-20	71.22	0.88	33.52	65.60
		20-25	72.84	0.34	34.08	65.58
		25-30	76.57	1.16	27.86	70.99
		30-35	56.00	1.44	50.97	47.59
		35-40	63.16	8.62	29.53	61.85

Appendix I (cont.): Grain size distribution taken at vertical increments along box cores.

Tributary	Station No. (Collection Date)	Depth Interval (cm)	%H_2O	%Sand	%Silt	%Clay
Patapsco River	P4 (4/24/81)	0-2	87.38	1.64	27.15	71.21
		2-5	76.29	2.67	24.98	72.35
		5-10	73.15	2.99	23.97	73.03
		10-15	68.45	3.59	24.09	72.32
		15-20	69.88	3.70	24.29	72.02
		20-25	67.41	4.31	24.54	71.15
		25-30	67.39	1.82	25.59	72.58
		30-35	66.43	2.56	23.90	73.54
		35-40	68.44	3.44	22.75	73.81
	P5 (4/27/81)	0-2	75.74	3.14	23.55	73.31
		2-5	73.46	4.21	22.21	73.58
		5-10	75.68	1.05	22.55	76.40
		10-15	77.19	0.99	21.60	77.41
		15-20	79.28	0.93	20.91	78.61
		20-25	76.99	1.28	20.72	78.00
		25-30	74.06	0.68	26.78	72.55
		30-35	71.65	0.54	13.12	86.34
		35-40	68.95	0.35	20.04	79.61
		40-45	69.33	0.22	20.85	78.93
		45-50	67.64	0.50	19.89	79.61
	P6 (4/27/81)	0-2	72.98	5.14	32.58	62.28
		2-5	67.94	3.53	31.64	64.82
		5-10	67.01	4.15	29.93	65.93
		10-15	71.38	4.36	29.91	65.73
		15-20	63.86	3.63	36.66	65.71
		20-25	70.71	1.97	29.40	68.63
		25-30	70.91	2.85	28.72	68.43
		30-35	69.09	0.83	29.58	69.58
		35-40	60.48	0.96	26.53	72.52
		40-45	63.89	0.27	27.10	72.63
		45-50	61.08	0.21	25.66	74.13
	P7 (4/28/81)	0-2	77.63	0.55	30.84	68.61
		2-5	77.98	1.03	29.81	69.16
		5-10	74.78	0.55	26.21	73.24
		10-15	75.46	0.87	24.60	74.53
		15-20	78.50	2.00	26.00	71.99
		20-25	65.85	19.94	23.29	56.76
		25-30	72.85	0.66	25.88	73.46
		30-35	75.24	3.80	26.06	70.14
		35-40	59.87	5.53	25.49	68.98
		40-45	58.68	4.41	26.25	69.34
		45-50	58.53	4.62	27.19	68.19

Appendix I (cont.): Grain size distribution taken at vertical increments along box cores.

Tributary	Station No. (Collection Date)	Depth Interval (cm)	%H_2O	%Sand	%Silt	%Clay
Patapsco River	P8 (4/28/81)	0-2	85.60	0.87	25.31	73.81
		2-5	78.30	3.69	25.56	70.75
		5-10	75.61	4.79	19.27	75.94
		10-15	70.53	5.76	21.27	72.97
		15-20	61.54	31.74	19.33	48.93
		20-25	57.11	22.05	20.73	57.22
		25-30	37.21	41.61	26.68	77.71
		30-35	38.32	45.82	29.18	24.99
		35-40	43.85	37.45	26.73	35.82
		40-45	51.81	14.06	26.44	59.50
		45-50	54.35	18.49	11.75	69.75
	P9 (4/28/81)	0-2	77.18	7.97	44.43	47.59
		2-5	74.51	5.92	42.69	51.39
		5-10	68.67	6.97	45.02	48.00
		10-15	70.82	6.32	41.99	51.69
		15-20	70.37	7.30	44.77	47.93
		20-25	73.66	5.00	43.78	51.22
		25-30	68.77	9.09	40.33	50.58
		30-35	74.00	3.78	35.90	60.32
		35-40	72.92	4.11	42.59	53.30
		40-45	67.98	3.29	38.99	57.73
	P10 (4/29/81)	0-2	74.86	0.56	31.41	68.03
		2-5	63.71	0.51	27.39	72.10
		5-10	63.52	0.83	27.43	71.74
		10-15	60.25	0.57	29.11	70.32
		15-20	60.55	0.32	29.59	70.09
		20-25	57.68	0.16	28.46	71.38
		25-30	63.08	0.25	30.18	69.56
		30-35	60.61	0.11	30.02	69.86
		35-40	59.16	0.10	29.27	70.65
		40-45	61.98	1.06	26.28	72.66
		45-50	56.19	13.02	26.03	60.96
	P11 (4/29/81)	0-2	66.87	1.72	25.51	72.77
		2-5	59.05	1.44	27.34	71.22
		5-10	57.51	6.52	27.23	66.25
		10-15	53.15	4.69	30.67	64.64
		15-20	52.40	5.61	32.75	61.64
		20-25	54.06	4.48	34.15	61.37
		25-30	61.50	3.66	34.42	61.92
		30-35	64.57	2.76	34.00	63.24
		35-40	63.17	2.52	35.39	62.09
		40-45	63.49	4.29	35.91	59.80

Appendix I (cont.): Grain size distribution taken at vertical increments along box cores.

Tributary	Station No. (Collection Date)	Depth Interval (cm)	%H_2O	%Sand	%Silt	%Clay
Patapsco River	P12 (4/30/81)	0-2	62.94	18.77	29.67	51.56
		2-5	57.77	12.57	31.34	56.08
		5-10	49.84	12.29	30.76	56.94
		10-15	53.12	7.57	32.70	59.73
		15-20	54.59	5.13	32.55	62.32
		20-25	57.77	5.21	34.14	60.65
		25-30	60.42	5.13	33.92	60.95
		30-35	57.77	3.64	37.02	59.34
		35-40	63.35	3.84	37.34	58.82
		40-45	62.69	5.38	37.96	56.67
	P13 (4/30/81)	0-2	58.76	7.35	46.12	46.52
		2-5	61.38	9.15	46.45	44.40
		5-10	55.55	7.44	46.91	45.65
		10-15	59.50	3.72	48.58	47.70
		15-20	57.45	4.51	47.20	48.29
		20-25	62.85	2.73	44.10	53.17
		25-30	55.88	6.48	42.37	51.14
		30-35	?	?	?	?
		35-40	60.45	1.37	41.64	56.99
		40-45	60.51	2.20	39.23	58.58
	P14 (4/30/81)	0-2	67.67	4.04	24.02	71.93
		2-5	59.08	2.53	17.45	80.02
		5-10	57.47	1.29	30.63	68.08
		10-15	60.51	1.00	31.21	67.79
		15-20	57.21	0.71	34.86	64.43
		20-25	60.34	0.40	22.26	77.34
		25-30	57.41	0.53	36.53	62.94
		30-35	58.31	0.44	29.39	70.18
		35-40	60.11	0.45	25.21	74.33
		40-45	56.95	0.43	28.55	71.02
Rhode River	R1 (5/4/81)	0-2	72.24	2.40	35.88	61.72
		2-5	67.67	2.27	36.76	60.97
		5-10	65.82	2.13	37.96	59.91
		10-15	63.92	2.21	36.18	61.61
		15-20	62.30	2.18	36.73	61.09
		20-25	59.27	1.97	35.55	62.48
		25-30	62.62	1.84	35.57	62.59
		30-35	59.33	2.07	35.31	62.63
		35-40	61.42	1.88	33.23	64.89
		40-45	61.40	2.25	32.58	65.17
		45-50	58.22	3.04	31.26	65.69

Appendix I (cont.): Grain size distribution taken at vertical increments along box cores.

Tributary	Station No. (Collection Date)	Depth Interval (cm)	%H_2O	%Sand	%Silt	%Clay
Rhode River	R2 (5/4/81)	0-2	62.63	7.64	48.01	44.35
		2-5	55.57	9.45	45.35	45.20
		5-10	56.86	7.12	49.06	43.82
		10-15	53.86	5.37	53.97	40.66
		15-20	57.17	5.78	44.35	49.87
		20-25	55.14	4.42	44.71	50.88
		25-30	56.44	4.32	45.24	50.44
		30-35	55.68	7.82	41.26	50.29
		35-40	60.43	2.96	26.81	70.23
		40-45	58.56	2.88	42.59	54.53
	R3 (5/4/81)	0-2	46.76	32.31	42.69	25.00
		2-5	40.29	31.98	42.92	25.10
		5-10	47.05	27.50	45.34	27.16
		10-15	?	?	?	?
		15-20	46.60	20.39	39.88	39.74
		20-25	42.36	26.04	45.14	28.82
		25-30	42.20	24.08	46.51	29.42
		30-35	45.12	24.55	44.27	31.19
		35-40	43.49	25.97	42.99	31.05
		40-45	45.00	19.72	44.14	36.14

Appendix II: Macrobenthic species collected in the Patapsco (P) and Rhode (R) Rivers.

PHYLUM RHYNCHOCOELA
- Family Lineidae
  - *Micrura leidyi* (P, R)

PHYLUM ANNELIDA
- Class Polychaeta
  - Family Capitellidae
    - *Heteromastus filiformis* (P, R)
  - Family Nereidae
    - *Nereis succinea* (P, R)
  - Family Phyllodocidae
    - *Eteone heteropoda* (P, R)
  - Family Spionidae
    - *Polydora ligni* (P, R)
    - *Scolecolepides viridis* (P, R)
    - *Streblospio benedicti* (P, R)
- Class Oligochaeta
  - Family Tubificidae
    - Oligochaete sp. (P, R)

PHYLUM MOLLUSCA
- Family Mactridae
  - *Rangia cuneata* (P, R)
- Family Myacidae
  - *Mya arenaria* (P)
- Family Tellinidae
  - *Macoma balthica* (P, R)
  - *Macoma mitchelli* (P, R)

PHYLUM ARTHROPODA
- Class Crustacea
  - Order Amphipoda
    - Family Corophidae
      - *Corophium lacustre* (P, R)
    - Family Photidae
      - *Leptocheirus plumulosus* (P, R)
  - Order Calanoida
    - Family Temoridae
      - *Eurytemora affinis* (P)
  - Order Cumacea
    - Family Bodotriidae
      - *Cyclaspis varians* (P, R)
  - Order Isopoda
    - Family Anthuridae
      - *Cyathura polita* (P, R)
    - Family Idoteidae
      - *Chirodotea caeca* (R)

Appendix II (cont.): Macrobenthic species collected in the Patapsco (P) and Rhode (R) Rivers.

PHYLUM ARTHROPODA
  Class Crustacea
   Order Thoracica
     Family Balanidae
       Balanus amphitrite (P)
  Class Insecta
     Family Tendipidae
       Chironomis sp. (R)

Appendix III. Species and abundance data for Patapsco (P) and Rhode (R) River stations.

Station P0

(4/22/81)

	Depth Interval (cm)			
	0-2	2-5	5-10	10-15
Oligochaetes				
Oligochaete sp.	2	1	-	-
Polychaetes				
Nereis succinea	-	-	-	1
Eteone heteropoda	19	2	1	-
Scolecolepides viridis	2314	325	3	-
Molluscs				
Macoma balthica	94	21	-	-

Station P1

(4/22/81)

	Depth Interval (cm)			
	0-2	2-5	5-10	10-15
Nemerteans				
Micrura leidyi	-	1	-	-
Oligochaetes				
Oligochaete sp.	2	6	1	-
Polychaetes				
Heteromastus filiformis	-	-	1	-
Nereis succinea	2	-	1	1
Eteone heteropoda	7	4	-	-
Scolecolepides viridis	872	134	5	-
Streblospio benedicti	3	-	-	-
Molluscs				
Macoma balthica	59	8	1	-

Station P2

(4/23/81)

	Depth Interval					
	0-2	2-5	5-10	10-15	15-20	20-25
Oligochaetes						
Oligochaete sp.	3	11	32	24	5	1
Polychaetes						
Nereis succinea	-	1	1	1	-	-
Scolecolepides viridis	178	79	9	-	-	-

Station P3

(4/23/81)

	Depth Interval		
	0-2	2-5	5-10
Oligochaetes			
Oligochaete sp.	-	2	-
Polychaetes			
Nereis succinea	-	-	1
Eteone heteropoda	12	4	-
Scolecolepides viridis	896	92	3
Streblospio benedicti	2	-	-
Molluscs			
Macoma balthica	18	2	-
Crustaceans			
Leptocheirus plumulosus	3	-	-
Corophium lacustre	1	-	-

Station P4

(4/24/81)

	Depth Interval				
	0-2	2-5	5-10	10-15	15-20
Polychaetes					
Heteromastus filiformis	-	-	2	-	-
Eteone heteropoda	18	13	4	-	-
Scolecolepides viridis	446	410	382	49	4
Streblospio benedicti	1	-	-	-	-
Molluscs					
Macoma balthica	76	37	-	-	-
Crustaceans					
Corophium lacustre	1	-	-	-	-

Station P5

(4/27/81)

	Depth Interval			
	0-2	2-5	5-10	10-15
Polychaetes				
Nereis succinea	-	-	1	-
Eteone heteropoda	5	-	-	-
Scolecolepides viridis	545	156	77	9
Molluscs				
Macoma balthica	21	-	-	-

Station P6

(4/27/81)

	Depth Interval							
	0-2	2-5	5-10	10-15	15-20	20-25	25-30	30-35
Oligochaetes								
Oligochaete sp.	-	1	-	-	-	-	-	-
Polychaetes								
Heteromastus filiformis	-	2	1	1	-	1	1	1
Nereis succinea	-	-	1	-	-	-	-	-
Eteone heteropoda	8	10	-	-	-	-	-	-
Scolecolepides viridis	64	99	24	-	-	-	-	-
Streblospio benedicti	10	3	-	-	-	-	-	-
Molluscs								
Rangia cuneata	1	-	-	-	-	-	-	-
Macoma balthica	75	13	2	-	-	-	1	-
Crustaceans								
Corophium lacustre	1	-	-	-	-	-	-	-

Station P7

(4/28/81)

	Depth Interval (cm)				
	0-2	2-5	5-10	10-15	15-20
Oligochaetes					
Oligochaete sp.	1	1	10	5	1
Polychaetes					
Heteromastus filiformis	-	-	3	2	-
Nereis succinea	-	-	1	-	-
Eteone heteropoda	8	1	-	-	-
Scolecolepides viridis	225	113	42	2	1
Streblospio benedicti	12	6	-	-	-
Molluscs					
Macoma balthica	63	19	12	1	-
Crustaceans					
Corophium lacustre	1	-	-	-	-
Leptocheirus plumulosus	3	3	-	-	-
Cyclaspis varians	2	-	-	-	-

	Station P8 (4/28/81) Depth Interval (cm)			
	0-2	2-5	5-10	10-15
Nemerteans				
Micrura leidyi	1	-	-	-
Oligochaetes				
Oligochaete sp.	-	-	1	-
Polychaetes				
Nereis succinea	-	-	1	1
Eteone heteropoda	5	8	-	-
Scolecolepides viridis	120	217	64	9
Streblospio benedicti	12	7	-	-
Molluscs				
Macoma balthica	52	28	7	-
Crustaceans				
Leptocheirus plumulosus	6	1	-	-

Station P9

(4/28/81)

	Depth Interval (cm)				
	0-2	2-5	5-10	10-15	15-20
Oligochaetes					
Oligochaete sp.	17	8	3	3	1
Polychaetes					
Heteromastus filiformis	-	1	-	-	1
Scolecolepides viridis	74	182	65	19	2
Molluscs					
Macoma balthica	12	-	-	-	-
Crustaceans					
Eurytemora affinis	1	-	-	-	-

Station P10

(4/29/81)

	Depth Interval								
	0-2	2-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40
Oligochaetes									
Oligochaete sp.	6	25	15	3	-	-	-	-	-
Polychaetes									
Heteromastus filiformis	2	3	9	5	3	4	3	1	2
Nereis succinea	-	-	-	-	-	-	1	-	-
Eteone heteropoda	6	-	1	-	-	-	-	-	-
Scolecolepides viridis	347	118	4	1	-	-	-	-	-
Streblospio benedicti	22	-	-	-	-	-	-	-	-
Molluscs									
Macoma balthica	6	9	-	-	-	-	-	-	-
Macoma mitchelli	1	1	-	-	-	-	-	-	-
Crustaceans									
Corophium lacustre	1	-	-	-	-	-	-	-	-
Leptocheirus plumulosus	4	1	-	-	-	-	-	-	-

Station P11

(4/29/81)

	Depth Interval								
	0-2	2-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40
Oligochaetes									
Oligochaete sp.	2	15	11	2	1	-	1	-	-
Polychaetes									
Heteromastus filiformis	-	5	6	4	2	-	3	2	1
Nereis succinea	1	1	2	-	-	-	-	-	-
Eteone heteropoda	12	2	-	-	-	-	-	-	-
Scolecolepides viridis	277	303	23	2	-	-	-	-	-
Streblospio benedicti	23	7	-	-	-	-	-	-	-
Molluscs									
Rangia cuneata	6	-	-	-	-	-	-	-	-
Macoma balthica	4	8	1	-	-	1	-	-	-
Macoma mitchelli	2	2	-	-	-	-	-	-	-
Crustaceans									
Leptocheirus plumulosus	4	-	1	-	-	-	-	-	-
Cyclaspis varians	1	-	-	-	-	-	-	-	-

Station P12

(4/30/81)

	Depth Interval (cm)						
	0-2	2-5	5-10	10-15	15-20	20-25	25-30
Nemerteans							
Micrura leidyi	-	-	1	-	-	-	-
Oligochaetes							
Oligochaete sp.	13	4	4	5	1	-	-
Polychaetes							
Heteromastus filiformis	14	5	3	2	-	2	2
Nereis succinea	6	3	1	-	-	-	-
Eteone heteropoda	22	3	-	-	-	-	-
Polydora ligni	13	-	-	-	-	-	-
Scolecolepides viridis	141	23	1	-	-	-	-
Streblospio benedicti	32	2	-	-	-	-	-
Molluscs							
Rangia cuneata	8	-	-	-	-	-	-
Macoma balthica	68	9	2	4	1	1	-
Macoma mitchelli	4	1	-	-	-	-	-
Mya arenaria	1	-	-	-	-	-	-

Station P12 (cont.)

(4/30/81)

	Depth Interval (cm)						
	0-2	2-5	5-10	10-15	15-20	20-25	25-30
Crustaceans							
Corophium lacustre	3	-	-	-	-	-	-
Leptocheirus plumulosus	14	1	-	-	-	-	-
Balanus amphitrite	1	-	-	-	-	-	-
Cyclaspis varians	8	-	-	-	-	-	-

Station P13

(4/30/81)

	Depth Interval (cm)								
	0-2	2-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40
Oligochaetes									
Oligochaete sp.	-	3	14	3	1	-	-	-	-
Polychaetes									
Heteromastus filiformis	2	4	26	15	7	4	5	2	1
Eteone heteropoda	1	1	-	-	-	-	-	-	-
Scolecolepides viridis	59	221	70	19	2	-	-	-	-
Streblospio benedicti	9	3	-	-	-	-	-	-	-
Molluscs									
Macoma balthica	5	14	2	-	-	-	-	-	-
Macoma mitchelli	-	3	5	1	-	-	-	-	-
Crustaceans									
Leptocheirus plumulosus	1	1	1	-	-	-	-	-	-

Station P14

(4/30/81)

	Depth Interval (cm)						
	0-2	2-5	5-10	10-15	15-20	20-25	25-30
Nemerteans							
Micrura leidyi	-	-	1	-	-	-	-
Oligochaetes							
Oligochaete sp.	46	18	2	-	-	-	-
Polychaetes							
Heteromastus filiformis	2	15	4	2	1	-	1
Nereis succinea	8	2	-	2	-	-	-
Eteone heteropoda	11	1	-	-	-	-	-
Scolecolepides viridis	11	1	-	-	1	-	-
Streblospio benedicti	41	1	-	-	-	-	-
Molluscs							
Rangia cuneata	1	-	-	-	-	-	-
Macoma balthica	40	1	-	10	2	1	-
Macoma mitchelli	1	-	-	-	-	-	-

Station P14 (cont.)

(4/30/81)

	Depth Interval (cm)						
	0-2	2-5	5-10	10-15	15-20	20-25	25-30
Crustaceans							
Corophium lacustre	1	-	-	-	-	-	-
Leptocheirus plumulosus	159	6	-	-	-	-	-
Cyclaspis varians	122	-	-	-	-	-	-
Cyathura polita	-	1	-	-	-	-	-

Station R1

(5/4/81)

	Depth Interval (cm)								
	0-2	2-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40
Nemerteans									
Micrura leidyi	-	-	1	2	-	-	-	-	-
Oligochaetes									
Oligochaete sp.	4	66	135	32	5	1	-	-	-
Polychaetes									
Heteromastus filiformis	1	1	4	3	5	2	4	2	1
Nereis succinea	-	-	-	1	-	-	-	-	-
Eteone heteropoda	6	-	-	-	-	-	-	-	-
Polydora ligni	5	1	-	-	-	-	-	-	-
Scolecolepides viridis	11	4	2	1	1	-	-	-	-
Streblospio benedicti	246	32	-	-	-	-	-	-	-
Molluscs									
Macoma balthica	386	22	3	-	2	3	2	-	-
Macoma mitchelli	4	1	2	2	-	-	-	-	-

Station R1 (cont.)

(5/4/81)

	Depth Interval (cm)								
	0-2	2-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40
Crustaceans									
Corophium lacustre	12	3	-	-	-	-	-	-	-
Leptocheirus plumulosus	996	34	4	-	-	-	-	-	-
Cyclaspis varians	218	-	-	-	-	-	-	-	-
Cyathura polita	-	1	2	-	-	-	-	-	-
Insecta									
Chironomus sp.	-	1	-	-	-	-	-	-	-

Station R2

(5/4/81)

	Depth Interval (cm)								
	0-2	2-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40
Nemerteans									
Micrura leidyi	1	1	-	1	-	-	-	-	-
Oligochaetes									
Oligochaete sp.	159	98	19	9	1	-	-	-	-
Polychaetes									
Heteromastus filiformis	1	6	14	12	8	5	3	4	3
Nereis succinea	-	-	2	-	1	-	-	-	1
Eteone heteropoda	3	-	-	-	-	-	-	-	-
Scolecolepides viridis	11	2	2	-	-	-	-	-	-
Streblospio benedicti	236	6	-	-	-	-	-	-	-
Molluscs									
Macoma balthica	95	4	3	7	7	1	-	-	-
Macoma mitchelli	10	3	-	-	-	-	-	-	-

Station R2 (cont.)

(5/4/81)

	Depth Interval (cm)								
	0-2	2-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40
Crustacenas									
Corophium lacustre	1	-	-	-	-	-	-	-	-
Leptocheirus plumulosus	637	10	2	-	-	-	-	-	-
Cyclaspis varians	117	-	-	-	-	-	-	-	-
Cyathura polita	1	-	-	-	-	-	-	-	-

Station R3

(5/4/81)

	Depth Interval (cm)							
	0-2	2-5	5-10	10-15	15-20	20-25	25-30	30-35
Nemerteans								
Micrura leidyi	-	1	1	-	-	-	-	-
Oligochaetes								
Oligochaete sp.	531	54	12	3	-	-	-	-
Polychaetes								
Heteromastus filiformis	32	24	38	10	7	3	3	1
Nereis succinea	1	-	1	2	1	-	-	-
Eteone heteropoda	4	-	-	-	-	-	-	-
Scolecolepides viridis	10	5	4	3	-	-	-	-
Streblospio benedicti	180	13	-	-	-	-	-	-
Molluscs								
Rangia cuneata	4	-	-	-	-	-	-	-
Macoma balthica	91	5	2	13	4	-	-	-
Macoma mitchelli	5	2	-	-	-	-	-	-

Station R3 (cont.)

(5/4/81)

	Depth Interval (cm)							
	0-2	2-5	5-10	10-15	15-20	20-25	25-30	30-35
Crustaceans								
Corophium lacustre	6	-	-	-	-	-	-	-
Leptocheirus plumulosus	410	7	-	-	-	-	-	-
Cyclaspis varians	131	-	-	-	-	-	-	-
Cyathura polita	4	-	2	-	-	-	-	-
Chirodotea caeca	3	-	-	-	-	-	-	-

Appendix IV: Representative radiographs of the Patapsco (P) and Rhode (R) Rivers.

Plate 1. Station P2: Polluted Environment

Station P2: Northeast branch of the Patapsco River head.
Latitude: $39^{o}16'43"$
Longitude: $76^{o}35'32"$
Sampling Date: 4/23/81
Water Depth: 25'
Radiograph negative print

Polluted Environment:

Thin interlayered mud and sand with sharp contacts characterize the peripheral branches and the head of the Patapsco. Silt and clay layers alternate with each other. Some disrupted sand laminae and sand lenses are apparent at depth. Methane gas cavities are also visible. Biogenic features are non-existent, probably because of extremely high sedimentation rates and the unstable (fluid) nature of the sediment.

Degree of Bioturbation: 0%

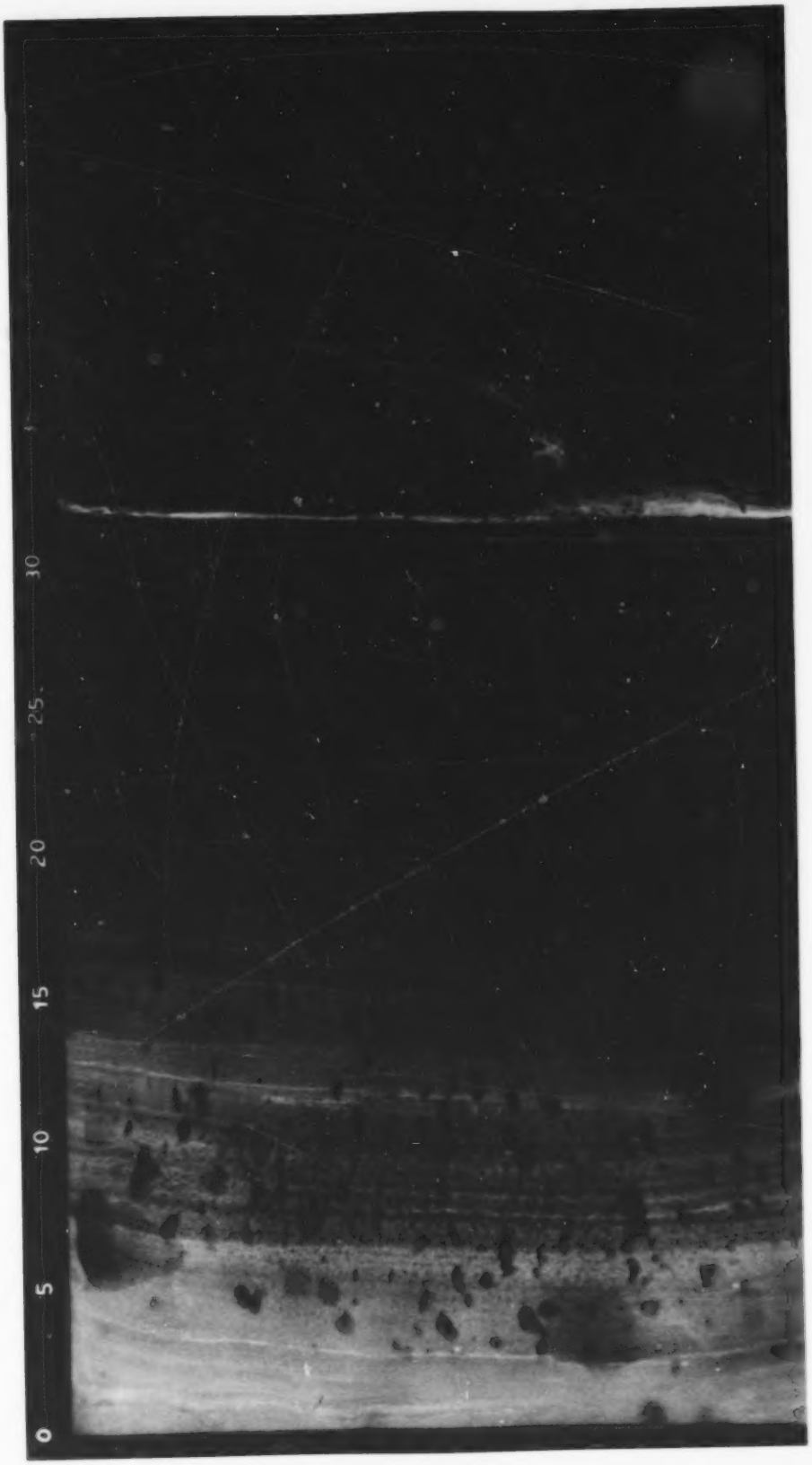

0
5
10
15
20
25
30

Plate 2. Station P9: Polluted Environment

Station P9: Within mouth of Bear Creek
Latitude: 39°13'51"
Longitude: 76°29'54"
Sampling Date: 4/28/81
Water Depth: 11'
Radiograph negative print

Polluted Environment:

Thin mud laminae (silt and clay) as well as thick mud beds are portrayed in this print. A few sand lenses are also apparent. Scattered slag fragments occur throughout the length of the core. An oyster shell lag deposit is evidenced along the bottom. Biogenic structures presumably belong to Scolecolepides viridis (polychaete - thin tube traces) and juvenile Macoma balthica (bivalve - thick burrows) species. Light halos around some biogenic features are the result of iron oxide precipitation. High sedimentation rates and the unfavorable geochemical milieu are thought to contribute to low bioturbation levels typical of many of the tributary branches.

Degree of Bioturbation: <30%

0
5
10

Plate 3. Station P1: Semi-polluted Environment

Station P1: Within the mouth of the northwest branch of the Patapsco River head
Latitude: 39°15'16"
Longitude: 76°36'02"
Sampling Date: 4/22/81
Water Depth: 17'
Radiograph negative print

Semi-polluted Environment:

Intermittent biologically and physically dominated activities are demonstrated in this print. Boundaries between sand and mud beds are rough. Small-scale cross bedding occurs within the thick sand bed. A dramatic laminar inclination of this sedimentary environment is apparent at depth. The sedimentary sequence at this station is thought to be due to periodic but intense dredging and spoil disposal activities.

Degree of Bioturbation: 10-30%

Plate 4. Station P7: Semi-polluted Environment

Station P7: Just outside of Hawkins Point
Latitude: 39°12'02"
Longitude: 76°31'11"
Sampling Date: 4/28/81
Water Depth: 14'
Radiograph negative print

Semi-polluted Environment:

Biogenically disrupted mud and sand laminae characterize many of the stations in the semi-polluted regime. A somewhat more distinct, bioturbated-free zone is found at depth. Shells and shell fragments, pebbles, and coarse sand particles are scattered throughout the sedimentary sequence. Thin tube traces of Scolecolepides viridis (polychaete) and funnel-shaped, backfilled burrows of Macoma balthica (bivalve) are clearly seen.

Degree of Bioturbation: 30-60%

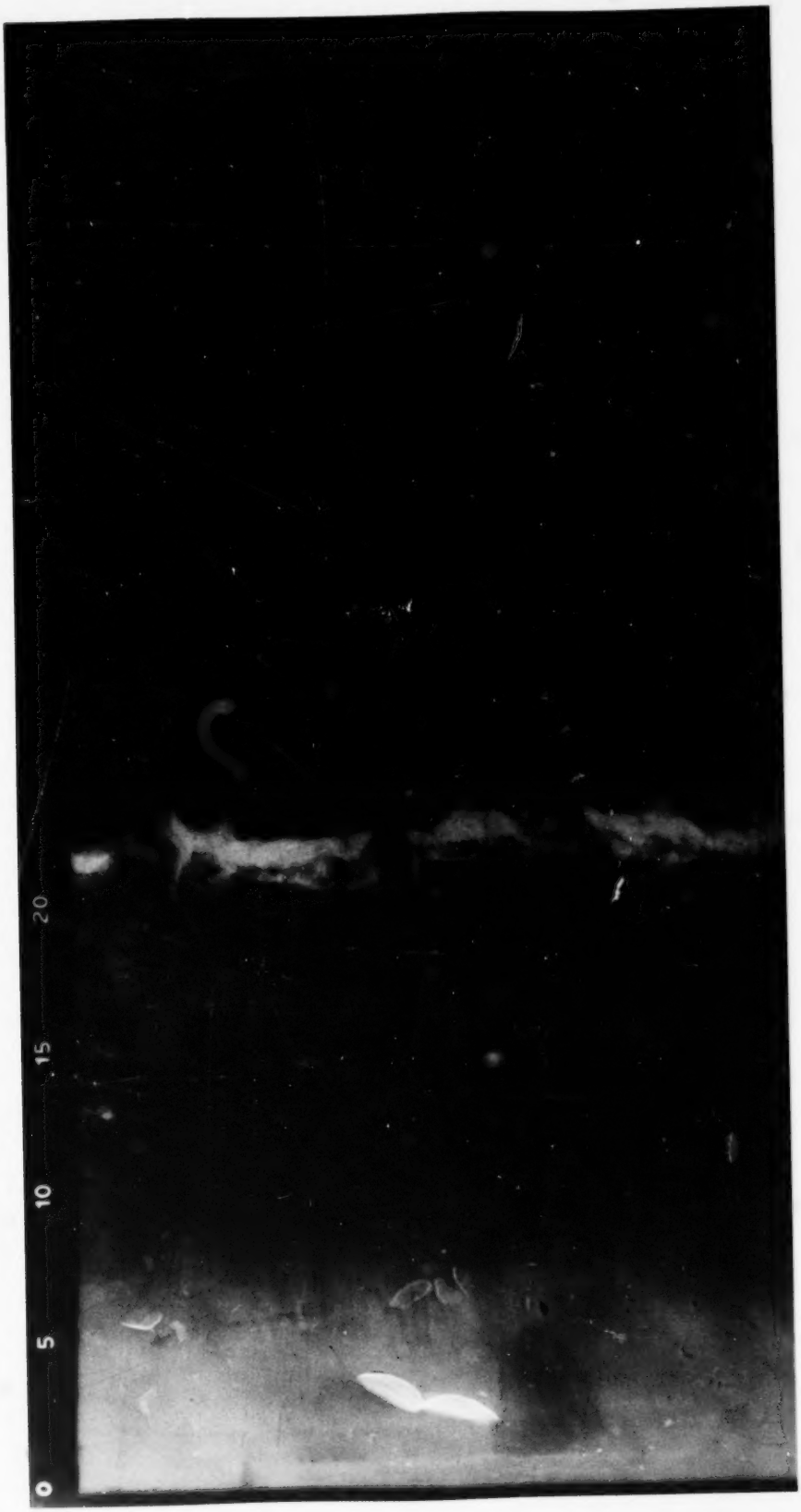

0
5
10
15
20

Plate 5. Station P10: Semi-healthy Environment

Station P10: Near White Rocks and Riviera Beach
Latitude: 39°10'52"
Longitude: 76°29'38"
Sampling Date: 4/29/81
Water Depth: 16'
Radiograph negative print

Semi-healthy Environment:

Biogenic activities are prominent at this station, becoming somewhat less prevalent at depth. A few thin mud laminae and some textural change (mud to sandy mud) are apparent at the bottom of the print. The dominant biogenic feature is that of the tube-builder, Scolecolepides viridis (polychaete). Macoma balthica (bivalve) and its funnel-shaped burrow are also evidenced. Shells of the bivalve, Rangia cuneata, represent a death assemblage.

Degree of Bioturbation: 60-90%

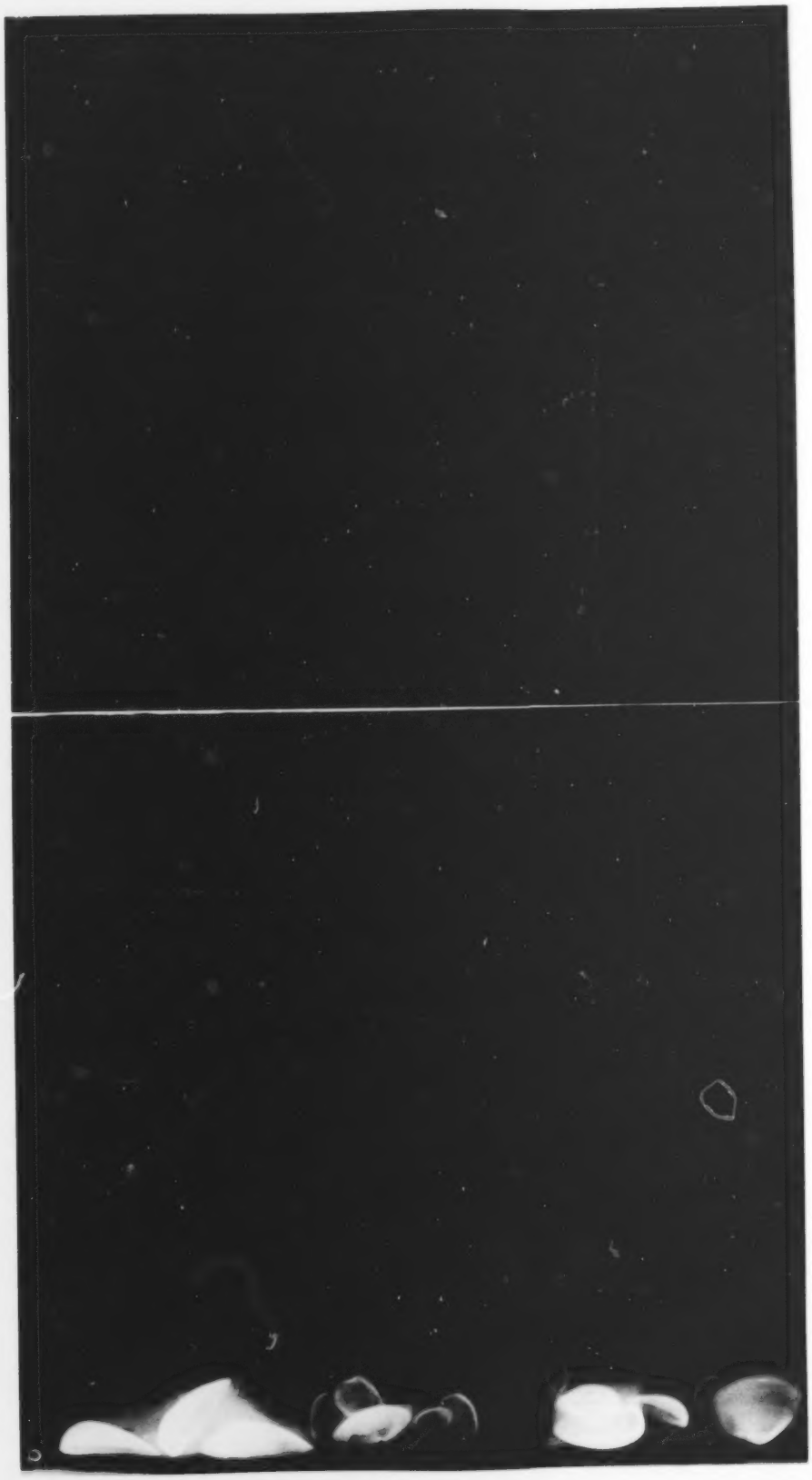
Plate 6. Station P14: Semi-healthy Environment

Station P14: Mouth of the Patapsco River
Latitude: 39°09'01"
Longitude: 76°23'25"
Sampling Date: 4/30/81
Water Depth: 20'
Radiographic negative print

Semi-healthy Environment:

Bioturbation levels are typically highest at the mouth of the Patapsco River. The greater diversity of certain faunal components leads to over-printing of biogenic features. Here, only the large vertical, funnel shaped burrows of Macoma balthica (bivalve), and some smaller reticulated burrow systems of Nereis succinea (polychaete) can be identified. The same Rangia cuneata death assemblage as that of Station P10 is seen at the sediment surface.

Degree of Bioturbation: 90-99%



Appendix V: ^{137}Cesium and pollen data for selected stations in the Patapsco (P) and Rhode (R) Rivers.

Station P1
(4/22/81)

Sediment Depth (cm)	cts/sec/g dry sed.	pico/Ci/g dry sed.
0-2	0.003000	0.790
2-5	0.003300	0.869
5-10	0.003350	0.883
10-15	0.003400	0.896
15-20	0.003950	1.041
20-25	0.003150	0.830
25-30	0.003600	0.948
30-35	0.004850	1.278
35-40	0.003400	0.896
40-45	0.003400	0.896

Pollen: No agricultural horizon

Station P2
(4/2/81)

Sediment Depth (cm)	cts/sec/g dry sed.	pico Ci/g dry sed.
0-2	0.006200	1.735
2-5	0.006150	1.721
5-10	0.004800	1.343
10-15	0.005650	1.581
15-20	0.005850	1.637
20-25	0.005300	1.483
25-30	0.005700	1.595
30-35	0.006800	1.902
35-40	0.005450	1.525
40-45	0.007500	2.098

Pollen: No agricultural horizon

Station P3
(4/23/81)

Sediment depth (cm)	cts/sec/g dry sed.	pico Ci/g dry sed.
0-2	0.005750	1.515
2-5	0.006050	1.594
5-10	0.005650	1.488
10-15	0.006350	1.673
15-20	0.003650	0.962
20-25	0.001050	0.277
25-30	0.003400	0.896
30-35	0.005300	1.396
35-40	0.002350	0.619
40-45	0.002550	0.672
45-50	0.002800	0.738

Pollen: Agricultural horizon (1840) possibly between 35 and 40 cm.

Station P5
(4/27/81)

Sediment depth (cm)	cts/sec/g dry sed.	pico Ci/g dry sed.
0-2	0.007800	2.154
2-5	0.006050	1.671
5-10	0.005000	1.381
10-15	0.005250	1.450
15-20	0.006250	1.726
20-25	0.002850	0.787
25-30	0.003850	1.063
30-35	0.003850	1.063
35-40	0.004200	1.160
40-45	0.004350	1.201
45-50	0.005150	1.422

Pollen: 1890 horizon possibly between 45 and 50 cm.

Station P7
(4/28/81)

Sediment depth (cm)	cts/sec/g dry sed.	pico Ci/g dry sed.
0-2	0.006150	1.620
2-5	0.004050	1.067
5-10	0.004500	1.185
10-15	0.003550	0.922
15-20	0.004400	1.159
20-25	0.001650	0.435
25-30	0.003600	0.948
30-35	0.003450	0.909
35-40	0.002700	0.711
40-45	0.003550	0.935
45-50	0.002950	0.777

Pollen: No agricultural horizon; evidence for resorting.

Station P9
(4/28/81)

Sediment depth (cm)	cts/sec/g dry sed.	pico Ci/g dry sed.
0-2	0.003700	1.022
2-5	0.003300	0.911
5-10	0.002950	0.815
10-15	0.004950	1.367
15-20	0.003250	0.897
20-25	0.002300	0.635
25-30	0.002350	0.649
30-35	0.001650	0.456
35-40	0.003950	1.091
40-45	0.002200	0.608
45-50		

Pollen: No agricultural horizon.

Station P10
(4/29/81)

Sediment depth (cm)	cts/sec/g dry sed.	pico Ci/g dry sed.
0-2	0.006400	1.767
2-5	0.004550	1.256
5-10	0.005250	1.450
10-15	0.005300	1.464
15-20	0.004550	1.256
20-25	0.004900	1.353
25-30	0.004100	1.132
30-35	0.004850	1.339
35-40	0.004150	1.146
40-45	0.009050	2.499
45-48	0.006650	1.836

Pollen: No agricultural horizon.

Station P14
(4/30/81)

Sediment depth (cm)	cts/sec/g dry sed.	pico Ci/g dry sed.
0-2	0.007250	2.028
2-5	0.007650	2.140
5-10	0.007450	2.084
10-15	0.009650	2.700
15-20	0.007550	2.112
20-25	0.005050	1.413
25-30	0.002850	0.797
30-35	0.004500	1.259
35-40	0.005150	1.441
40-45	0.004200	1.175
45-50	0.003650	1.021

Pollen: No agricultural horizon; evidence for resorting.